International Engineering Congress,
GLASGOW, 1901.

SECTION I.

RAILWAYS.

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PROCEEDINGS.

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BOMBAY BRANCH

OF THE

Royal Asiatic Society.

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International Engineering Congress,

GLASGOW, 1901.

MEETING

HELD AT

THE UNIVERSITY, GLASGOW,

ON THE

3rd, 4th and 5th SEPTEMBER, 1901.

PROCEEDINGS OF SECTION I.

RAILWAYS.

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GLASGOW, 1901.

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Meeting held at the University, Glasgow, 1901.

SECTION I.

PROCEEDINGS OF SEPTEMBER 3.

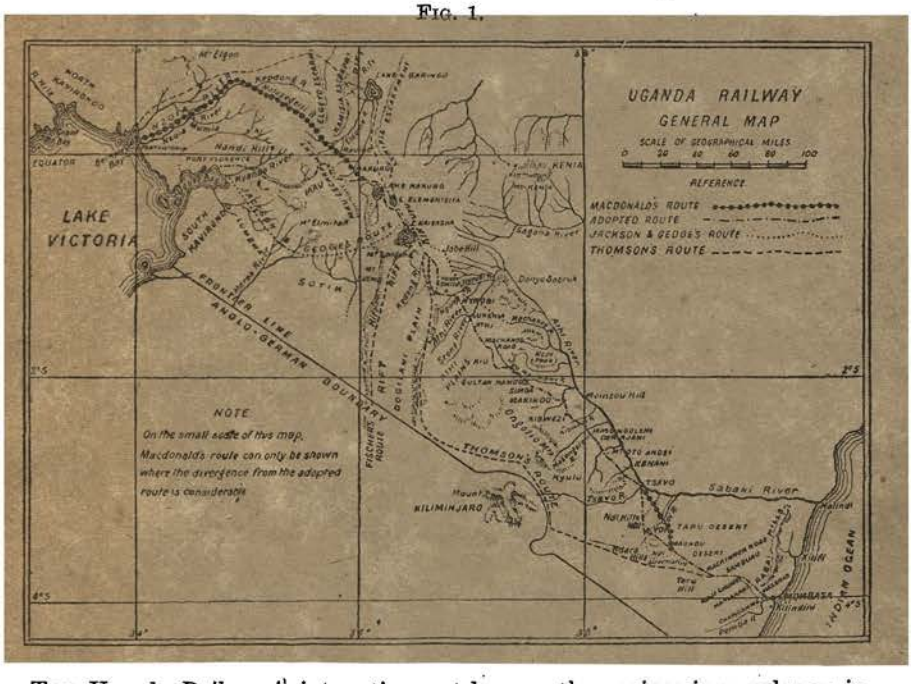
Sir Benjamin Baker, K.C.M.G., D.Sc., LL.D., F.R.S., in the Chair.

[Paper.]

THE UGANDA RAILWAY.

By Sir Guilford L. Molesworth, K.C.I.E., Member of Council Inst.C.E.

Fig. 1.



The Uganda Railway is interesting, not because the engineering works are in any way remarkable, but because it affords valuable experience:—

(1) On the manner in which information may be acquired and inferences deduced from the careful study of maps and books of travel in an almost unknown country, even when the sources of information are very meagre.

(2) It furnishes an excellent example of an extremely able reconnaissance on an astronomical and barometrical basis.

(3) It stands unique in the combination of difficulties very different from those usually encountered by engineers in railway construction.

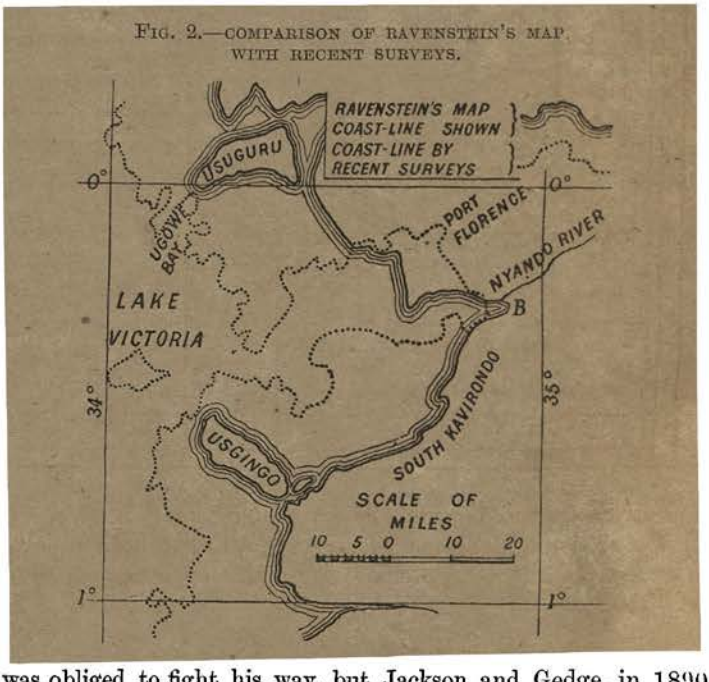
Early in 1891, I was requested to advise the Imperial British East Africa Company on the preliminary steps to be taken for opening railway communication between the East Coast of Africa and Lake Victoria. The problem was very difficult. I had never been in the country, which was then very little

known. McDermot, Secretary to the Imperial British East Africa Company, wrote [1] :—

"The countries north of Kiliminjaro were, in the year 1888, *terra incognita*, the only European who had succeeded in penetrating to the Victoria Nyanza being Mr. Joseph Thomson, in his rapid and necessarily superficial expedition through Masailand. What was known of the rest of the region was the result of conjecture or of native reports gathered by missionaries."

Stanley had visited Lake Victoria *viâ* the Congo, and Fischer in 1883 had passed through German territory by the Dogilani Plain to Navasha. Stanley's advice to Thomson before he started on his expedition was, "Take a thousand men or make your will." Thomson, however, started with 150 followers, but being threatened by a large body of Masai, he had to return, and was only able to proceed by joining a large caravan of traders. Fischer, with a caravan

FIG. 2.—COMPARISON OF RAVENSTEIN'S MAP WITH RECENT SURVEYS.

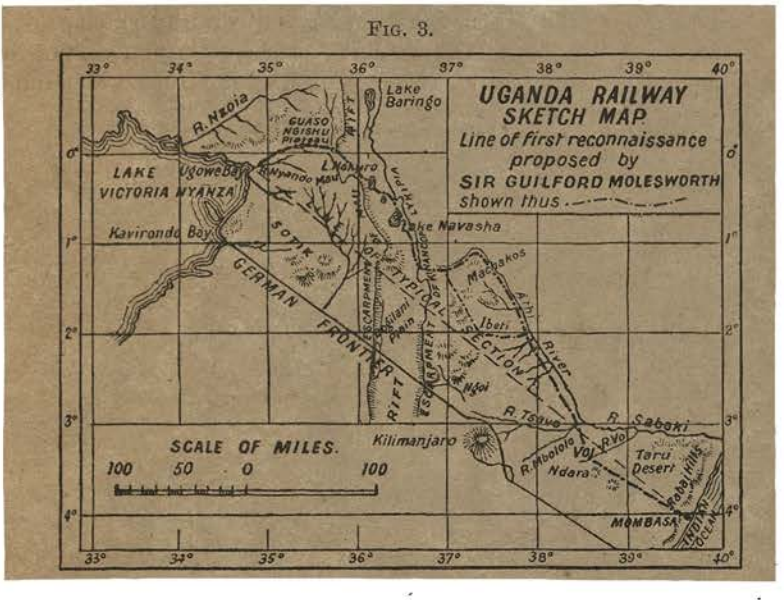


of 600, was obliged to fight his way, but Jackson and Gedge, in 1890, with 535 followers, passed through the district without any serious fighting. Ravenstein's valuable map was compiled chiefly from these sources under the auspices of the Royal Geographical Society, but the information in it was necessarily meagre and sketchy and in some points inaccurate, as may be inferred from Fig. 2, in which the coast line, as shown in Ravenstein's map, is compared with the results of more recent and detailed surveys. In Ravenstein's map the point B at the mouth of the River Nyando was marked as "Ugowe Bay," whereas that bay is actually about 48 miles distant from it. In spite of these defects, however, the map was of the greatest assistance, and in fact the inferences and deductions on which I based my report were gleaned almost exclusively from it and from the records of the expeditions of Thomson

[1] "British East Africa" (Chapman & Hall), p. 207.

and of Jackson, which had been published in the proceedings of the Royal Geographical Society of December, 1884, and April, 1891, respectively. None of those who had traversed the district had viewed it with the eyes of an engineer looking to its possibilities for railway communication. But little information had been given of the character of the two escarpments which bounded a great volcanic rift, and I was unable to find any record of the visit of a European to the Mau plateau or to the valley of the Nyando River. After a careful study of these sources of information, I recommended as the first line for reconnaissance the route shown on sketch map, Fig. 3.

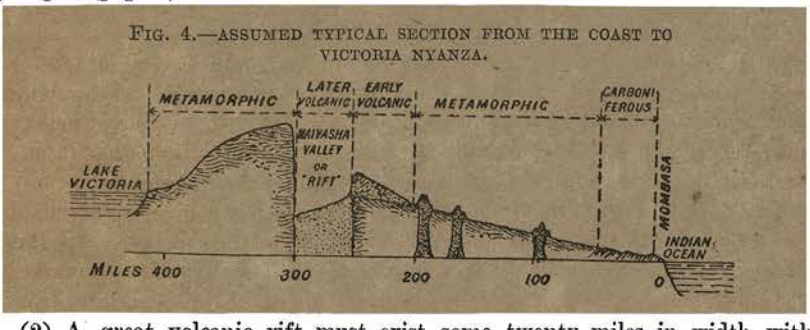
FIG. 3.



This advice was based on the following inferences :—

(1) The section of the country on a straight line between Mombasa and the mouth of the Nyando River would probably be approximately as represented by Fig. 4 (page 2).[1]

FIG. 4.—ASSUMED TYPICAL SECTION FROM THE COAST TO VICTORIA NYANZA.



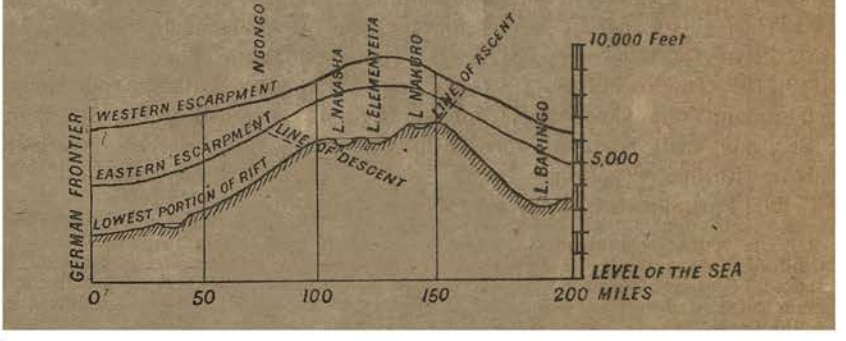
(2) A great volcanic rift must exist, some twenty miles in width, with escarpments on each side varying from 1,500 to 2,000 feet in height (pages 2 and 4).[1]

[1] Page of Sir G. Molesworth's Report of 1st May, 1891, to the I. B. E. A. Co.

(3) A chain of lakes indicated that this rift extended from German territory right through British possessions, and therefore could not be avoided (page 2).[1]

(4) The longitudinal section of the rift and its escarpments might be assumed approximately as indicated in Fig. 5 (page 6).[1]

FIG. 5.—ASSUMED LONGITUDINAL SECTION OF THE RIFT AND THE ESCARPMENTS AT EITHER SIDE OF IT.



(5) Close to the coast the Rabai Hills, some 700 feet high, had to be rounded (page 4).[1]

(6) Voi was an obligatory point in the railway for the purposes of the water supply (page 5).[1]

(7) The land from the Rabai Hills to the edge of the rift would probably rise steadily to an elevation of about 5,000 feet (pages 2 and 4).[1]

(8) The Tsavo River should be crossed between its confluence with the Sabaki River and the point where the Mbololo River joins it (page 4).[1]

(9) Machakos must be avoided either by the valley of the Athi or by an alternative route (page 4).[1]

(10) The configuration of the Athi River indicated the probability of a low saddle in the escarpment, and a favourable approach to the rift near the point marked Ngongo on the map (page 3).[1]

(11) The descent of the eastern escarpment should take place in the direction of the rising floor of the rift, as shown in the longitudinal section of the rift (page 6).[1]

(12) The line should keep along the floor of the rift, past the lakes Navasha, Elmenteita, and Nakuro, until the culminating point of the rift was reached (page 6).[1]

(13) An easy line would probably be obtained in the floor of the rift at this part (page 6).[1]

(14) The most favourable point for ascending the Mau or western escarpment was near Lake Nakuro (page 6).[1]

(15) Advantage might be taken of the fall of the escarpment by ascending in the direction of that fall (page 6).[1]

(16) A railway by Jackson's route *viâ* Sotik was impracticable (page 7).[1]

(17) The only probable chance of obtaining a favourable railway was by

[1] Page of Sir G. Molesworth's Report of 1st May, 1891, to the I. B. E. A. Co.

descending to Lake Victoria from Mau by the valley of the Nyando River (page 7).[1]

(18) To attempt to take the line further north would involve a considerable detour and very broken ground (page 7).[1]

(19) Beyond Ngongo, excepting the portion in the floor of the rift, the line must be difficult of construction and very costly (page 8).

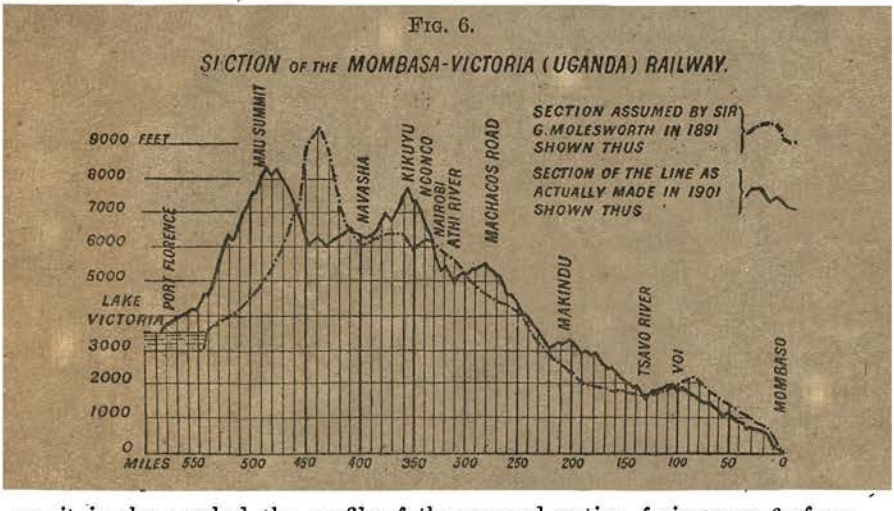
In July, 1891, being requested by the Lords of the Treasury to furnish them with an estimate of such a preliminary reconnaissance as I had suggested, I advised them that it would not be prudent to estimate the cost of an expedition for that purpose at less than £20,000. The actual cost was £19,710. In November, 1891, the expedition started under the command of Captain (now Colonel) Macdonald, R.E., accompanied by Captain Pringle, R.E., and their reconnaissance entirely confirmed the inferences as deduced above with one exception.

The Parliamentary Report of 1893 states :—

"The route recommended for the projected railway is practically that which Sir Guilford Molesworth, in his report on the proposed railway dated the 1st May, 1891, states: 'Presents the only probable chance of obtaining an inexpensive railway,' the main point of difference being that the valley of the Nzoyia River is followed down to the Lake Victoria instead of the Nyando River."

This change involved a detour which would have added about 100 miles to the length of the railway, but in 1898, Mr. Blackett, an engineer engaged in the permanent survey of the railway, discovered that the route by the Nyando Valley was quite feasible, and the railway is now being constructed there. Fig. 6 is a section of the railway now in course of construction, and

FIG. 6.



on it is also marked the profile of the assumed section, facing page 6 of my report of May, 1891.

The assumed section was under the supposition that, in the avoidance of Machakos, the Athi Valley route might be taken, whereas the alternative route was actually adopted. Macdonald reported that the Athi Valley route would

[1] Page of Sir G. Molesworth's Report of 1st May, 1891, to the I. B. E. A. Co.

have an easier gradient and more carrying power; but, on political and commercial grounds, he recommended the alternative route. Mr. Whitehouse, the chief engineer in construction, instead of descending the eastern escarpment at the point I had suggested, kept the line further along the edge of the escarpment, thus rising to a higher summit level, but also obtaining a more favourable line and one which admitted of pushing forward the rail-head with greater rapidity by means of a temporary rope incline. The summit level at Mau, on the western escarpment, was lower than I had anticipated, and the length of the railway was longer, as shown by the comparative sections.

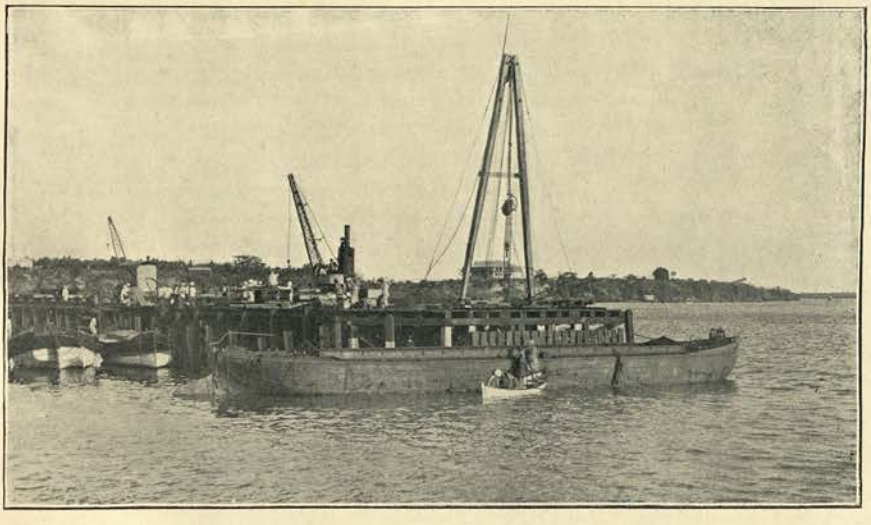
It is difficult to speak too highly of the able manner in which Macdonald's reconnaissance was carried out. His map has been of the greatest value both to the railway and to the Protectorate, and its accuracy has been tested by surveys of the railway and of the Military Intelligence Department. The mode of procedure in this reconnaissance was as follows: The daily route was traversed with compass, aneroid barometer and pedometer; and the plan plotted in the field. The general slopes of the country at right angles to the traverse were observed with Abney levels. By a combination of these cross-sections with barometric observations, the plans were approximately contoured at vertical intervals of 100 feet; a section was at the same time prepared from the barometric readings, corrected as far as possible for the daily wave, which is very important in the tropics, and for atmospheric changes. These field plans were re-plotted in camp, linked together by triangulation where feasible, and otherwise by astronomical observation, and were amplified by sketching in the surrounding country by means of plane tables set up on commanding points. The dense nature of the bush and want of time preventing regular triangulation, astronomical observations were made to check the positions occupied at the end of each day's march, one or other of the following methods being used as was found suitable:—(*a*) Latitude and azimuth observations to any well-defined point previously fixed to north or south by camp; (*b*) latitude and distance observations, where the only previously determined points lay east or west of the camp, the distance being determined by measuring a short base and taking theodolite or sextant observations from either end; (*c*) when the above two methods failed, the position of the camp was determined by latitude and longitude observations, the latter depending for their accuracy on the ratings of watch-chronometers; (*d*) observations for absolute longitude were taken whenever opportunity occurred of occultations, either of a star by the moon or Jupiter's first Satellite, and thereby the ratings of the chronometers were checked.

During halts of 24 hours or over, diurnal wave-curves were made for each aneroid barometer, and instruments were frequently checked and adjusted. Notes were made during each day's march on the following points: number and position of all small waterways crossed, breadth and height of banks, high flood marks, nature of soil in bed and banks, slope of bed, and depth of water in any of all streams of 20 feet width and upwards, and of the general physical and geological features of the country.

The difficulties which have been encountered in the construction of the railway were very great, and mostly of a character which do not usually fall to the lot of a chief engineer in construction.

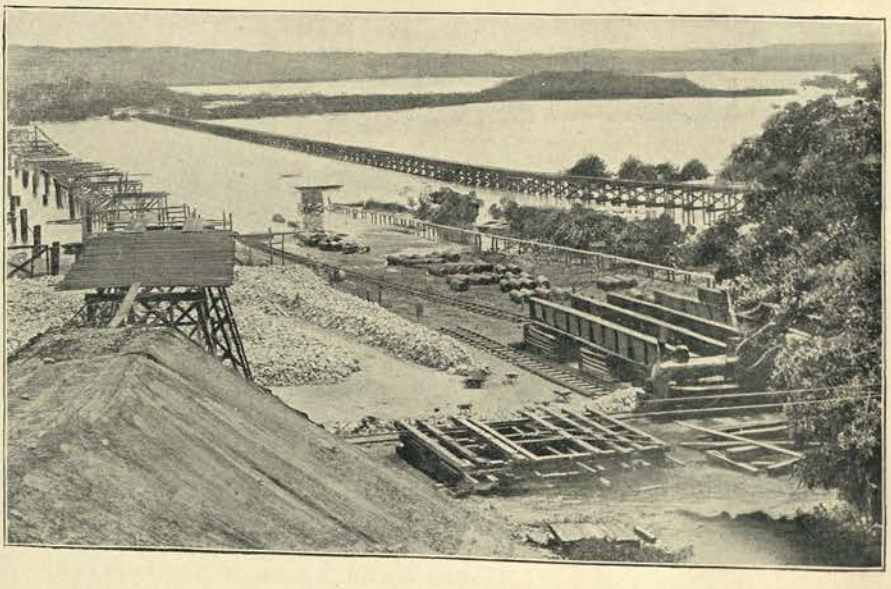
KILINDINI HARBOUR AND JETTIES.

MAIN JETTY : KILINDINI.



THORNY JUNGLE.

VIADUCT OVER MACUPA CHANNEL.



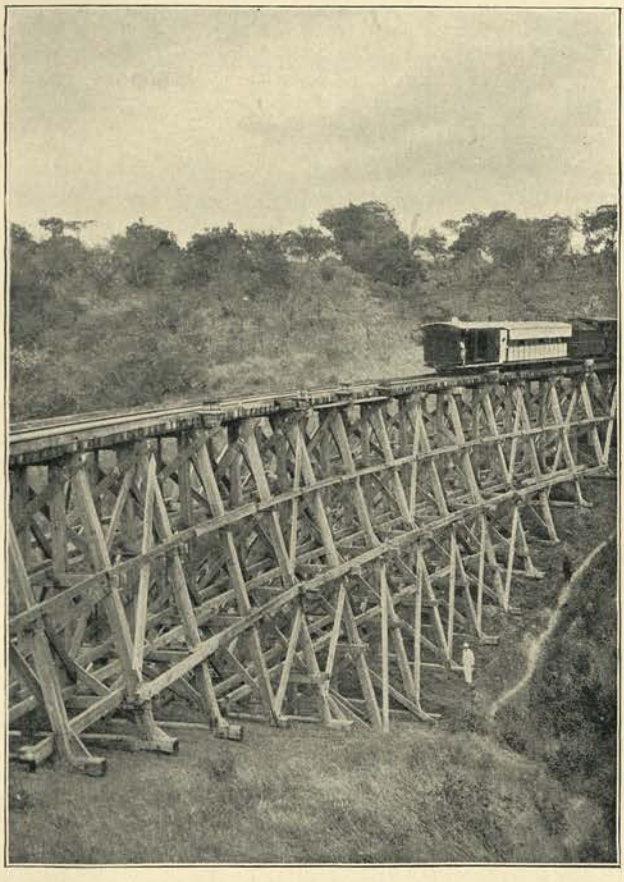
Mombasa is a small Arab seaport, with scarcely any facilities for landing stores, cramped in anchorage, and exposed to the monsoon. A new port had to be established at Kilindini, which is a magnificent land-locked natural harbour. The first question demanding the attention of the engineer on his arrival was the provision for landing and storing railway materials; extensive jetties had to be constructed, and during their erection all stores had to be landed on a shelving beach. The land rises abruptly from the beach, increasing the difficulty of bringing materials to the depot; a short line with gradients of one in fifty had to be constructed from the jetties to the railway terminus. A steam launch and lighters had to be provided, cranes erected, moorings laid down, store-sheds built, and harbour arrangements made. About eighty-five per cent. of the labour had to be imported from India, and the importation was hampered by plague regulations in India. The labourers had to be housed on arrival. The members of the engineering staff were new to each other, to the country and to its language. They had to be organised and their special qualifications ascertained. Many of the subordinates obtained from India or picked up locally proved to be incapable or inebriates. Those subordinates who were sent from England were, on the other hand, for the most part very satisfactory. No supplies were available in the country; even the poles and thatch for coolie houses had to be procured from some distance up the coast and brought down in dhows. The district was in a disturbed state, raiding parties of savages having penetrated close to Mombasa, and the first survey parties could not be sent out unless protected by military escort. The construction of the railway involved an organisation equivalent to that of the maintenance of an army of about 15,000 men in a practically waterless country devoid of resources, and of all means of animal or wheeled transport; with a base of operations to which everything had to be imported from a distant country. The utmost foresight had to be exercised owing to the great length of time required for postal communication. Materials had to be carried from rail-head to the advanced working and survey parties, and it was impossible to keep any very large working party far in advance of rail-head. Traction engines were found useful in this service. The loads taken by the porters were limited by the fact that they had to carry their own food in addition to their loads. Throughout the Taru Desert was a thick thorny, impenetrable jungle affording no shade. The first 250 miles was infested by the tsetse fly, which is fatal to transport animals; and nearly all the imported animals, 62 camels, 128 mules, 259 bullocks, and 774 donkeys died. Jiggers abounded in the country, causing ulcers which, if not taken in time, necessitated the amputation of one or more toes. Man-eating lions pervaded the district to such an extent that there was a panic amongst coolies, twenty-eight of whom were killed, some being taken out of their tents or from railway trucks. Lion-proof buildings had to be erected, and the coolies were run out by train every evening from the worst part and brought back in the morning. Waves of fever were common in the country; one such wave occurred during my visit to the country in 1899, and I found on my arrival at one station that the locomotive foreman and eleven out of twelve drivers were on the sick list, and in one working gang 280 out of a total of 320 were down with fever. It was not, however, of a virulent type, and the mortality

was small; but very extensive hospital arrangements had to be maintained. Separate water-trains had to be run for the supply of the working parties and permanent-way gangs; and every engine had to take a heavy water tank to supplement the tender. Not only had the food of labourers to be imported, but a corn-mill had to be erected to grind the imported wheat. A large condensing apparatus had to be established to supplement the water supply at Kilindini terminus. Water, even where procurable, was so bad that the engines had to be washed out after every day's run, and an abnormal quantity of engines were required in consequence. The engineers' strike in England delayed the supply of railway materials and engines, and some second-hand engines twenty years old had to be procured from India to push on the work. These engines were too light for the severe gradients of the temporary diversions, and required very heavy repairs. The line had to be constructed telescopically, and it was found impossible to maintain any large working gangs far in advance of rail-head. It was of vital importance to push forward the rail-head at any cost; in fact, the policy of rapid progress of the rail-head saved the situation in Uganda at a very critical time by enabling troops to be carried through the waterless district. It was necessary to make diversions wherever possible to save time by temporary avoidance of heavy work on the permanent line, which was left to be finished at leisure. The rail-head at the time of my visit to this country had nearly reached 300 miles from the coast, although the permanent line through the Rabai Hills, or about twelve miles from Mombasa, was incomplete for some time afterwards. Many of these temporary diversions entailed heavy work with curves of 400 feet radius, and gradients of 1 in 30. In the first 300 miles there were 34½ miles of such diversions; amongst these were the temporary bridge, one-third of a mile in length, over the Macupa Channel, which separates the island of Mombasa from the mainland (*see illustration*), and the Mazeras trestle bridge (*see illustration*). The former was finished in ninety-one working days, and the latter in twenty-five working days. Under ordinary conditions, this would have been a very creditable performance; but when it is considered that the work was commenced by entirely untrained workmen under a newly-organised staff, it has been a very remarkable feat, creditable to the organisation and to all concerned in it.

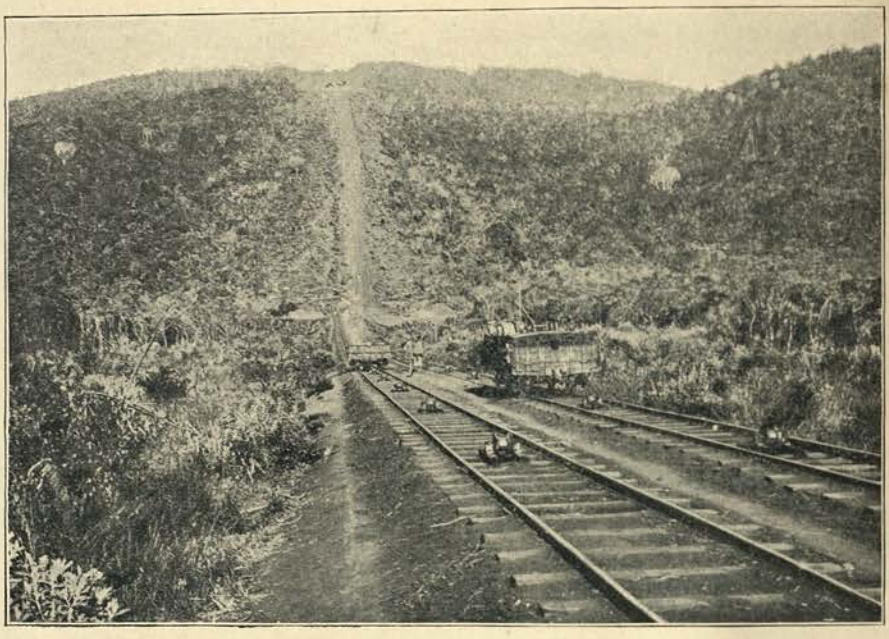
Another important temporary work was the rope incline for lowering materials into the rift from the eastern escarpment, pending the construction of the permanent line down that escarpment. This rope incline consisted of four separate inclines, two of which averaged about 1 in 2, and two about 1 in 7, above and below the steeper inclines, the total descent of the four inclines being about 1,500 feet, with a total length of about 6,000 feet (*see illustration of rope incline*). This temporary diversion enabled rail-head to be advanced more than 100 miles further than would have been possible by the permanent line, and will probably save a year in the time of reaching Lake Victoria.

An agency for the supply of labour and materials from India had to be established; a postal service into the interior, with a regular mail, arranged. Complete hospital arrangements and medical staff at headquarters, and at different parts at which the permanent line was being constructed, as well as at rail-head, had to be organised. A police force of 200 men had to be

MAZERAS TRESTLE BRIDGE.



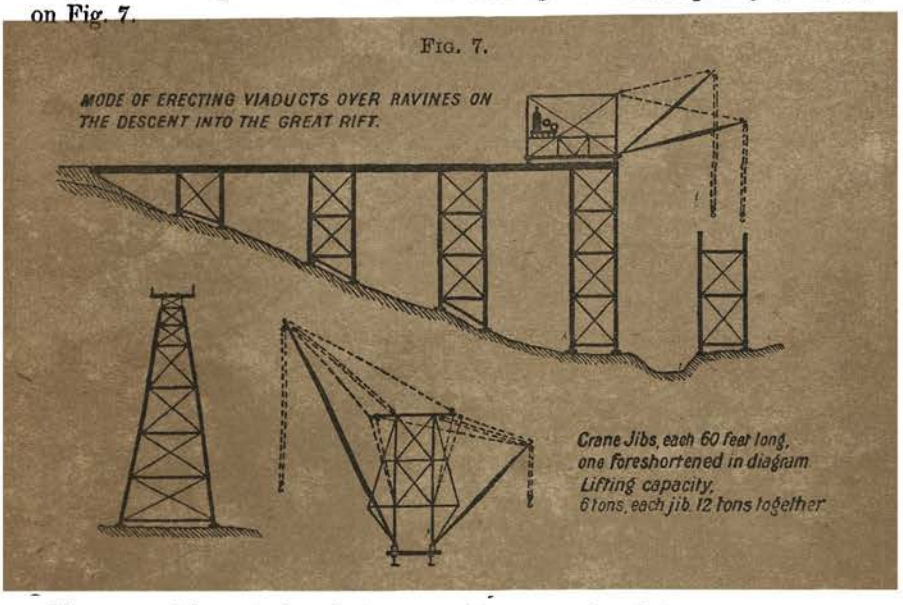
ROPE INCLINE: FOOT OF No. 3 INCLINE.



CARRIER ON ROPE INCLINE.

disciplined and maintained. A temporary telegraph line had to be laid for the Protectorate in advance of the rail-head, and this was constantly disturbed by rhinoceros, elephants, or large game. A small steamer had to be carried in sections by porters through jungle paths, and put together at Lake Victoria. This had twice been attempted unsuccessfully before the arrival of the railway staff. As soon as practicable, sections of the line were opened for public use; traffic arrangements had to be made, and the construction was hampered by the working of the ordinary traffic. In the descent of the western escarpment several ravines have to be crossed. The type of viaduct that has been adopted and the mode of erecting them telescopically is shown on Fig. 7.

FIG. 7.


MODE OF ERECTING VIADUCTS OVER RAVINES ON THE DESCENT INTO THE GREAT RIFT.
Crane Jibs, each 60 feet long, one foreshortened in diagram
Lifting capacity, 6 tons, each jib 12 tons together

The supervision of the whole, comprising commissariat, accounts, transport, traffic, stores, harbour arrangements, repairing locomotives and rolling stock, medical and hospital arrangements, and the numerous details which make up the complex organisation of this railway, in addition to the ordinary work of survey and construction, has rested on Mr. Whitehouse, the chief engineer, and great credit is due to him and to his staff for the manner in which they have carried out the work under circumstances of unparalleled difficulty.

DISCUSSION.

The CHAIRMAN: Gentlemen, time absolutely precludes any adequate discussion of this extremely interesting Paper, but if anyone present wishes to make some remarks, I hope he will be as brief as possible.

Mr. A. E. WELBY: Mr. Chairman and Gentlemen, I have lately returned from the Uganda Railway, where I have been for five years. I feel, in being called upon to make a few remarks, that it is difficult to know where to begin, because there is such a great deal of valuable information, and I can hardly say which is of the greatest interest to engineers. I think the most interesting thing to those actually connected with the work of the Uganda Railway was the survey. In many places it was no easy matter to get a good line through, the country being so rough and rising to such altitudes. The highest point of the line, or rather its summit, is where the Mau escarpment rises to an altitude of 8,323 feet in a distance of 500 miles. Without going into much detail, I may say it is obvious that a great deal of difficulty must be met with in getting the line through. In many places we were very much tied as to grade, the maximum grade being one in fifty, and the curves, on the permanent line, 800 feet radius. The temporary grades were allowed to be 3 per cent., or one in thirty; the radius here was 400 feet. Of course, we avoided temporary lines as much as possible, but they had to be adopted in a great many places. For the first 200 miles, with the exception of the line near Mazeras, there was not much temporary work. The heavy temporary work of this sort was the Macupa bridge, as was pointed out in the paper. The permanent bridge, which took more than two years to complete, has 21 spans of 60 feet each, and 5 spans of 12 feet. The temporary bridge was of wood, which required a great deal of looking after, on account of the toredo, the destroying ant. After crossing to the mainland, the biggest temporary work was to Mazeras. I feel that there is so much to say about this railway that I hardly know how to proceed, and as I have not prepared any speech, I think perhaps I ought to let some of you ask me some questions and I will answer them.

The CHAIRMAN: I wish we had the whole day to spend in discussing this Paper. Perhaps you will kindly send in some notes upon it to the Secretary of this section.[1]

Mr. WIGHAM RICHARDSON: I should like to be informed what gauge this railway is?

Sir GUILFORD MOLESWORTH: The metre gauge, 3 feet $3\frac{3}{8}$ inches.

Mr. WIGHAM RICHARDSON: Is that the same as the gauge of the railroads in Egypt?

Sir GUILFORD MOLESWORTH: No.

The CHAIRMAN: As no other gentlemen appear desirous of asking questions, I will ask you to accord a vote of thanks, which I have great pleasure in proposing, to Sir Guilford Molesworth for his Paper on the Uganda Railway. The line is one in which he has taken a most distinguished part, and its description is a matter of very great interest. (*Carried by acclamation.*)

[1] *See* p. 11.

Additional Notes on the Uganda Railway.

[Contributed, at the Chairman's request, by A. E. Welby.]

As Sir Guilford Molesworth states, the Uganda Railway stands unique in a combination of difficulties very different from those usually encountered by engineers in railway construction. Both Sir Guilford Molesworth's preliminary report and Colonel Macdonald's reconnaissance survey were of great value to the chief engineer and staff who surveyed and constructed the railway, and it is highly satisfactory that the railway has been built, to a very great extent, on the alignment as suggested by them.

The survey from the Mau escarpment to the Lake Victoria Nyanza *viâ* the Nyando Valley is very creditable, great care having been required to fit in the limiting curves and gradients, and it is extremely interesting to note that this route was adopted as originally suggested by Sir Guilford Molesworth, thereby saving nearly 100 miles in the length of the railway to the lake, as compared with Colonel Macdonald's subsequent reconnaissance survey.

As regards the Kikuyu temporary inclines, which were adversely reported upon by Colonel Gracey (Africa, No. 6, 1901)—he being of opinion that they were unnecessary—it would be presumption on my part to venture an opinion; neither is there profit to argue the advantages of alternative routes after the line has been made; but it might be remarked that, from what was gathered from a reconnaissance survey, an alternative route as suggested by Sir Guilford Molesworth *viâ* Ngongo was practicable, and heavy work would have been encountered on this as well as on the route adopted.

The following may be of interest to note:—

(1) That the rails used were steel flange rails, weight 50 lbs. to the yard, laid on steel sleepers and keyed. This makes a thoroughly good road and repays for the additional cost as compared with wooden sleepers in a country where the latter do not last. When the sleepers have been well packed, the road requires little attention except during the rains. There are no derailments caused by the spreading of the gauge, as is the case with rails spiked on wooden sleepers. On curves of a sharp radius, a slightly wider gauge can always be obtained by keying on the inside of the rails.

(2) That cement concrete was largely used in abutments and piers of bridges, good stone for masonry being seldom obtainable near the site of the works. Lava was found useful for concrete work, although some lava was extravagant in cement on account of being porous.

(3) That corrugated iron sheets, bent to a circle and rivetted, make good temporary culverts; and that wooden sleepers, stacked transversely and longitudinally, make good temporary abutments or piers.

(4) That traction engines were of great service in taking material, food supplies, etc., in advance of rail-head. They were also useful in pulling girders into position and quicker than the ordinary methods by hand.

(5) That coral is of great value for ballast and for building permanent piers. The wooden pier at Kilindini, having become rotten, is now being filled in between the piles with coral, and will form a solid block and make an excellent permanent pier.

Mr. ALEXANDER ROSS, M.Inst.C.E., in the Chair.

[PAPER.]

THE ECONOMY OF ELECTRICITY AS A MOTIVE POWER ON RAILWAYS AT PRESENT DRIVEN BY STEAM.

By Professor C. A. CARUS-WILSON, M.A., Assoc.M.Inst.C.E.

THIS Paper deals briefly with the question of the economic considerations which will probably govern the substitution of electricity for steam as a motive power on railways.

It is generally acknowledged that the branch lines are the least profitable part of a railway system, and that in many cases the receipts per mile are barely sufficient to pay expenses. There is also evidence that in the near future the unremunerative character of the branch lines will become still more marked, since the traffic they at present carry is being seriously menaced by the network of electric tram lines that is spreading in all directions throughout the country.

To pay expenses with steam traction it is necessary to make up trains of considerable length, so that where the traffic is small, as on branch lines, the interval between trains is large. This results in a poor service between towns and districts connected only by branch lines, and gives rise to considerable difficulty and delay in making connections at main-line stations. Thus, while main-line travel is popular, cross-country travel is unpopular.

The infrequency of the service on branch lines is responsible for much of the unpunctuality that exists. The limited traffic does not permit of an adequate staff being maintained to deal with it as it might and should be dealt with if it were more evenly distributed over the day. The employees are not uniformly occupied, and the infrequent arrival of long trains with large numbers of passengers and corresponding quantities of luggage renders prompt handling of the traffic very difficult, and causes delay and unpunctuality which often affects the main-line traffic itself.

If the train service on the branch lines could be broken up into smaller units moving more frequently, cross-country travel would be greatly facilitated and the punctuality improved.

An increase in the frequency of any given service of trains at once affects the intimate relation which exists between facility of travel and the traffic resulting therefrom. While it is an accepted axiom that increased facilities create traffic, yet the increase may be obtained at too great a cost. It is thus of importance to ascertain upon what the cost of any given increase in the train service depends, so as to be able to deduce the minimum traffic required to pay for such increase.

To do this the cost of working the line under the existing conditions with steam must be divided into two parts, and the running expenses per train-mile, which vary with the number of trains run, must be distinguished

from the fixed expenses, which do not so vary. The former will include principally coal, drivers' and conductors' wages, and repairs, while the latter will include the maintenance of the permanent way, traffic expenses, rates and taxes.

The fixed expenses per train-mile multiplied by the number of trains per day on any given line, under the existing conditions, gives the contribution of that line per day-mile to the general fund for purposes of maintenance, etc. This will then constitute a fixed sum per day-mile to be provided for under the new conditions, together with the increased running expenses. The traffic per day-mile must exceed this amount, plus a sum required to pay the interest on the electric installation, before the line can be said to pay.

The working expenses of the principal English railways, taken from the Board of Trade Returns for the year 1900, are given in Table I. In these

TABLE I.

Working expenses and proportion of goods and passenger traffic for the principal English railways for the year 1900.

	A	B	C	D	E	F
	Train-miles.		Goods tons per train-mile	Expenses per train-mile.		
	Goods.	Passenger.		Fixed.	Running.	Total.
	%	%		*d.*	*d.*	*d.*
London & North Western	46	54	1·97	31·4	11·1	42·5
Great Western	50	50	1·62	25·1	11·0	36·1
Great Northern	50	50	1·45	22·9	11·4	34·3
Great Eastern	41	59	1·31	28·0	10·3	38·3
Midland	60	40	1·43	22·6	11·6	34·2
London & South Western	27	73	1·34	31·6	10·6	42·2
Lancashire & Yorkshire	35	65	3·33	30·1	11·5	41·6
South Eastern & Chatham	22	78	2·00	34·4	13·0	47·4
London, Brighton & South Coast	19	81	2·10	32·5	12·8	45·3
Cheshire Lines	44	56	2·80	28·8	13·9	42·7

returns no distinction is drawn between the cost of operating passenger trains and goods trains, neither is there any indication given of the weight of the trains hauled. It seems very desirable that the railway companies should furnish the passenger and goods ton-mileage as they now furnish train-mileage, for these figures, taken conjointly with the cost of working, must be the true basis of all endeavours to reduce the proportion of unprofitable mileage.

In Table I. the total working expenses per train-mile given in column F are divided into two parts in columns D and E. In column D are given the fixed expenses, including maintenance of way, etc., repairs and renewals of carriages, traffic expenses, rates and taxes, miscellaneous and legal. In column E are given the running expenses, including wages, coal, water, and locomotive repairs. Columns A and B give the goods and passenger train-miles respectively, in percentage of total. Column C gives the goods tons carried per goods train-mile.

Columns B and D show how the fixed expenses increase with the passenger traffic. Thus, with the Midland, where the passenger train-mileage

is 40 per cent. of the whole, the fixed expenses are only 22·6 pence per train-mile. With the Great Western and the Great Northern, where the goods and passenger train-miles are equal, the fixed expenses vary from about 23 to 25 pence, while on the southern lines, where the passenger traffic is about 80 per cent. of the whole, the fixed expenses amount to as much as 32 to 34 pence per train-mile. An increase in the passenger traffic need not, however, be accompanied by a rise in the fixed expenses; for if the traffic were evenly distributed over the working day, a considerable increase could be dealt with by the existing staff. For this reason the amount of the fixed expenses assumed in the following comparison will be taken for a line with an average amount of passenger traffic, as for instance the Great Northern, where the fixed expenses are 22·9 pence.

The figures in column C indicate the character of the goods traffic on each line, *quâ* weight. Taken in conjunction with column A, they give some idea of the relative weights of the goods trains hauled on the different lines. Comparing these columns with column E, it will be seen that in spite of the variation in the weights hauled, and in the proportion of goods and passenger traffic, the item for running expenses is very nearly the same on the first seven lines. Thus the Midland, with 60 per cent. of goods train-miles and 1·43 tons per train-mile, has the same running expenses as the Lancashire and Yorkshire with only 35 per cent. of goods train-miles, but with 3·33 tons per train-mile. On the Great Eastern and on the London and South Western a low percentage of goods train-miles and a low weight per train-mile combine to give the lowest figures of all the lines for running expenses. The South Eastern and the London and Brighton are about equal to the Great Eastern in the matter of goods traffic, and the running expenses would also be nearly the same were it not for the high price both the former lines had to pay for coal last year. The figures for the Cheshire Lines illustrate still further the fact that the running expenses do not rise above the average unless there is a large proportion of unusually heavy goods traffic.

Taking the Great Northern again as a representative line, the running expenses may be subdivided as shown in Table II., which gives the actual figures in the report for the last half-year of 1900, the total differing slightly from the returns for the whole year. The coal item is, of course, abnormally large, the average price of coal during 1900 having been about 10*s.* 9*d.* Reducing this figure to the equivalent for coal at 8*s.* a ton, we get 3·36, bringing the cost per train-mile down to 10·33 pence.

TABLE II.

Running expenses of the Great Northern Railway for the last half-year of 1900.

Wages	3·81	pence per	train-mile.
Coal	4·50	,,	,,
Water, oil, etc.	0·77	,,	,,
Repairs, wages	1·34	,,	,,
,, materials	1·05	,,	,,
Total	11·47	,,	,,

The wages of the guard of the train should be included in the above figure, in order that it may represent the whole of the expenses, which vary with the number of trains run. Taking the wages of a driver at 42*s.* per

week, of a fireman at 22*s.*, and of a guard at 25*s.*, the item "wages" under running expenses should be increased by 1·52 pence. This amount must be also deducted from the fixed expenses, giving us finally 21·38 pence per train-mile as the expenses which do not, and 11·85 pence as the expenses which do, vary with the number of trains run.

We can now take the case of a branch line with, say, six trains each way per day. The running expenses will be 12 × 11·85 or 142 pence, and the fixed expenses 12 × 21·38 or 256 pence per day-mile. Hence, if the line in question is to pay expenses, that is, to contribute to the general revenues a sum proportional to the number of trains run, and to the average cost per train-mile for the whole line, the receipts per day-mile must amount to 398 pence, or the traffic, estimated in equivalent numbers of third-class passengers, must be 398 per day-mile.

Instead of a steam-driven train every two hours we may have an electrically-driven train every half-hour, or twenty-four each way per day instead of six, each of the new trains having seating accommodation equal to one-fourth of one of the original trains. The new trains may consist of motor-cars driven by motors under the car, and ordinary carriages trailing. By getting rid of the locomotive about 20 per cent. of dead weight is saved, and since the weight of the carriages will be one-fourth of that in the original train, the new trains will weigh one-fifth of the old trains. This will reduce the coal item in the running expenses to 0·68 pence per train-mile, and that for water, oil, etc., to 0·15 pence, as shown in Table III.

TABLE III.

Running expenses in pence per train-mile.

	Steam.	Electricity.	Liverpool Overhead Railway.
	d.	*d.*	*d.*
Coal	3·36	0·68	0·85
Wages of driver and assistant	3 81	1·24	1·15
„ conductor	1·52	1·01	1·01
„ at generating station	—	0·62	0·69
Water, oil, etc.	0·77	0·15	0·42
Repairs, wages	1·34	0·67	0·40
„ materials	1·05	0·52	0·65
Total	11·85	4·89	5·17

The coal consumed per ton-mile is here taken to be the same for an electric generating station driving electric motors on the cars as for steam locomotives. This probably does not give the electric system full credit for the economy obtained by using large engines in the power-house and motors of high efficiency, but there is not as yet sufficient experience to warrant any material reduction being made in the coal item when comparing the two systems.

The cost of repairs will be reduced. On the City and South London Railway the cost of wages and materials for repairs to electric rolling-stock and generating station is 0·92 pence per train-mile, about 38 per cent. of that on the Great Northern. Taking 50 per cent. as a moderate estimate, we get

0·67 pence per train-mile for wages and 0·52 for materials for repairs to electric motor cars and to the generating station.

A large reduction can be made under wages. The great simplicity of the electric equipment enables us to substitute for the highly-paid driver and his fireman one motor-man, say, at 32*s.* a week, thereby halving the wages item on the locomotive. Further, as the electric motor is ready to start at any moment a great deal of time is saved during the week when compared with the steam locomotive, which has to spend a considerable amount of time in the shed and in getting up steam. Also, with the increased service a larger proportion of the actual working hours will be usefully employed. In consequence of this economy of time the men can put in about 50 per cent. more train-miles than before, and the wages item is reduced to 2·25 pence per train-mile. To this must be added the wages of the men engaged in the generating station, which may be taken at 50 per cent. of the motor-man's wages, or 0·62 pence per train-mile, making the wages per train-mile altogether 2·87 pence. The total cost per train-mile for running expenses with the electric train is thus 4·89 pence, as compared with 11·85 pence for the original steam train.

The running expenses on the Liverpool Overhead Railway for 1899 are given in Table III. Comparing these with the figures already obtained it will be seen that the item for wages is almost the same, while the items for coal, oil, etc., are higher on the Liverpool line, and for repairs slightly less. The item for conductor's wages has been taken to be the same in both cases. The trains on the Liverpool line are made up of motor cars and trailers weighing together about 40 tons loaded. About 180 trains are run each way per day, with a total of 403,000 train-miles in the year (1899); this large train-mileage of course reduces the fixed expenses per train-mile to a low figure, but does not affect the running expenses.

With the new system the fixed expenses would be the same as before, while the running expenses would increase in proportion to the increase in the frequency of the service, that is, in the case assumed, fourfold. Hence the fixed expenses will be 256 pence per day-mile and the running expenses 48 × 4·89, or 240 pence, making a total of 496. So that in order to pay expenses the traffic would have to increase from 398 per day-mile to 496, or 25 per cent. This increase, however, would not pay the interest on the capital required for the electrical equipment.

The cost of the electrical generating station, with distributing system and rolling-stock for a half-hour's service of 40-ton trains on a line not exceeding, say, 15 miles in length, would probably be about £8,000 per mile. At 3½ per cent. interest this would mean an additional 184 pence per day-mile, making the total increase of traffic required to pay all expenses and interest 70 per cent.

In Table IV. similar figures are given for services of three and four trains in the hour. The capital required increases slightly with the number of trains.

The increase of traffic resulting from a given increase in the frequency of the service depends upon local conditions, but if a fourfold increase in the number of trains per day were to double the traffic, the profits per day-mile would be 10 shillings. If the traffic were trebled the profits would be 43 shillings. The average profits per day-mile for the whole of the Great

Northern Railway system is about 124 shillings, so that the use of electricity on branch lines is certainly worth consideration as a means of making them yield a more substantial proportion of the total profits than they do at present.

TABLE IV.

These figures give, in pence per day-mile, the cost of working an electrical line as compared with a steam line.

	Steam.	Electricity.		
No. of trains each way per day	6	24	36	48
	d.	*d.*	*d.*	*d.*
Fixed expenses.	256	256	256	256
Running expenses	142	240	360	500
Interest on electrical installation . . .	—	184 (*a*)	230 (*b*)	276 (*c*)
Total.	398	680	846	1,032
Increase in traffic to pay expenses . . .	—	70 %	110 %	158 %

(*a*) at £8,000 a mile. (*b*) at £10,000 a mile. (*c*) at £12,000 a mile.

DISCUSSION.

The CHAIRMAN: The subject which Professor Carus-Wilson has dealt with is one which is engaging the attention of engineers all over the country at the present time, and I cannot help thinking there should be considerable discussion upon it.

Mr. HURRY RICHES: May I trouble you with one or two remarks with reference to this Paper? I came here very anxious to hear the latest that I could as to the proposition of working our railways by electricity, and I am bound to take exception to a few of the remarks Professor Carus-Wilson has made. I do not think it is quite fair to make the comparisons which he, in some cases, has drawn. He deals with the cost of working the branch traffic, and does not appear to me to have taken into consideration—because I understand him to mean that goods as well as passenger traffic can be dealt with—the cost of transhipment from the electrically arranged plant on one side with the main-line vehicles on the other; and as it will be an item of cost incurred by the company, it does not appear to be a matter whether it is locomotive cost or cost for handling goods. It is all cost to the company, and therefore that cost should be included in the total for the transference of goods from one point to another.

In the second place, I cannot quite agree to his method of "day-mile." Let me give you one illustration. Professor Carus-Wilson deals with the Great Northern Railway, and gives that as an instance of a day-mile, and then compares the day-mile of the tramway and branch lines. I think that is hardly fair, because a large percentage of the traffic hauled on the Great Northern Railway would be traffic taken at a much higher speed than would probably be the case in a branch-line traffic, whether dealt with by steam or by electricity. Therefore I do not think the day-mile is at all a fair comparison. We railway men are in the habit of taking the train-mile or the ton-mile as a standard, and I think it is a fairer one. The question of the day-mile should not be the standard. The speed, the distance travelled, and the loads hauled must affect the result.

In the next point dealt with by the Author, he rather based his calculations upon the cost of hauling passenger traffic only, and there he very justly said that the Board of Trade returns did not define whether it was passenger or mineral cost. From a fair amount of experience in taking these items out, I may say that the passenger cost as a rule runs to about 60 per cent. of the mineral cost. The Author also suggested running four electric trains instead of one steam train. That, I quite agree, is a convenience to the public, but he certainly must have four gangs of men and four electric trains, as against one gang of men on the steam train. That appears to me to show the fallacy of dealing with the cost of the day-mile. Then he also said that the electric car was always ready to start; but we assume that the electric car must be furnished with electric power, therefore the generating station machinery must start, and if that is so, why not the locomotive? It is as

difficult to get a start with the one as the other. So much for my adverse statements with regard to Professor Carus-Wilson's Paper.

I very cordially agree that the time is rapidly approaching when at least the express traffic of this country will have to be dealt with by electric motors, but I cannot help thinking, in face of the enormous amount of money which is at present locked up in British railways, that some other method during the transition period must be adopted than the overhead trolley system, or central rail, or anything of that kind. It seems to me that the only possible solution, for many years to come, of the difficulty attached to the express traffic of the country—which, in my opinion, is the first to be dealt with—is that the engine of the train itself must generate its own power. I quite believe that the present form of locomotive is not that in which the locomotive of the future will have to be built. You will want a great deal more power in dealing with the rapidly growing trains. There is a large amount of adhesion which might be utilised for tractive purposes. Take, for instance, a train where there are 200 tons weight on the various wheels. At present only about thirty-five tons of that adhesion is used for tractive purposes, whereas if there were a motor upon each axle it would be most useful for propelling the load. I maintain that electrical engineers should face this problem rather more on the lines I suggest, namely, that the power should be generated on the train, and circulated, in fact, through all its axles. I cannot help thinking that that is the first line to be taken. I am quite aware that in France some experiments have been made in that direction, but accumulators were used; they have not, however, been extended. I am strongly of opinion that it is probably in this direction that the more immediate change in the propulsion of high-speed passenger traffic in this country will occur, and I hope electrical engineers will seriously take into consideration the suggestion I have ventured to make, with the view to utilising the adhesion of all the wheels in the train, and to better purpose than at present.

Sir DOUGLAS FOX: We are much indebted to Professor Carus-Wilson for having brought this subject forward. It is far too intricate and difficult a subject to treat in a short discussion at a meeting of this kind, but I am convinced that the problem is one which will have to be met in the course of a few years, not only by electricians, but by railway engineers. Our American friends have experienced the absolute necessity, on their main lines in the neighbourhood of their larger cities, of reforming their mode of working suburban traffic, and I am quite convinced that similar steps will have to be taken very shortly if our main lines are to maintain their supremacy in opposition to the electric tramways that will very speedily spread on all sides. I agree with the last speaker as to the probable way in which an early solution of the difficulties might be found. If only the researches which have been made—and to my knowledge with some success—towards the establishment of a really light accumulator, could be brought to a certain point, it would be far easier for the main lines to accommodate themselves to the frequency of trains on their suburban branches, than it would be possible for them if they had to think of either the overhead trolley-wire or the conductors mixed amongst the ordinary rails, thus

exposing their men to serious injury. I think there can be no doubt that electricity has the great advantage of being a rapid starting and stopping power, and in suburban traffic its great advantage comes into play.

I do not see any difficulty with reference to the point raised by the last speaker as to the transhipment of goods, because in dealing with the ordinary branch lines there would be no difficulty in goods being carried forward by electric power. But the point is not the working of branch lines and running infrequent trains, so much as enabling the existing railways which have large suburban traffic to avail themselves of this wonderful and growing power. This must be done in such a way as to work in, at present at any rate, with locomotive power, and to do that some plan must be found, as the last speaker stated, by which the present arrangements can go on smoothly, without undue interference with the electric force that is to be introduced on to the system. If something of this kind is not adopted by the large lines, they will very soon find that their suburban traffic will be reduced to a minimum.

Professor C. A. CARUS-WILSON: There seems to be very little necessity for my taking up your time, except to reply to the remarks of the two speakers who have raised one or two points. I wanted particularly to draw your attention in this Paper to the great suitability of electricity for frequent service. It is for that reason that electricity will come in, affording great benefit to our railways, whether suburban or non-suburban. For suburban traffic it has a great future; I assume that we are all agreed on that point. I did not, however, refer to suburban traffic in my Paper, but to the future of electricity on railways forming part of a great system, and it is on those parts of such railways, where the present system seems to break down, that electricity will come in and afford what is needed by the public, that is, a more frequent service. We know how much inconvenience is caused through the country by infrequent service on all but the main lines. Those who have felt that inconvenience must see that some action must be taken to provide a more frequent service; it appears to me that electricity can provide that service, and that before long the attempt must be made, which I believe will be successful.

I am sorry to have to disagree with Mr. Hurry Riches, who expressed the belief that electricity would come in first on express railways. It seems to me that it is not primarily on high-speed and long-distance lines that electricity is going to be of value in developing our railway facilities. As to accumulators, in the distant future no doubt they may be made so light that they may be carried on express trains, but at present we know of no such accumulator, and it does not appear to me that anything of the kind is within the range of practical politics. We know what we can do with motors driven by electricity distributed from a central power station; it is on this knowledge I have based the remarks in the Paper. It appears to me that it will be some time before electricity is used for long-distance express lines, but that we shall soon see electricity used on short lines, in order to give a more frequent service.

Mr. HURRY RICHES: I did not suggest accumulators.

Professor C. A. CARUS-WILSON: I know you did not. With regard to the use of the term "day-mile," I admit that that is an innovation, but I

think perhaps there is some justification for it. Wherever we find railway affairs spoken of, or reports or statistics given, it is always on the basis of the train-mile. It seems to me that what we want to get at is what part of the railway systems are unprofitable, and to what extent? The only way of doing that is to take a given mile of railway and consider what that mile pays to the general revenue. Then the question is, does it pay the expenses incident to the traffic running over it? What does that particular section earn per day, week, or year? I wish that our railway managers would tell us what is not published in the Board of Trade Reports, but is of more value than much that is in those reports, viz., what really are the relative earnings of each mile of line on the great railway systems. I should not be surprised to find that the main lines earned 80 per cent. of the total, and that the great network of short lines hardly paid expenses. The railways should endeavour to reduce this unprofitable mileage, or let the electric tramways come in and do the work.

Then again we want to know not only what does each mile of line cost to work and what does it earn, but what does it cost to haul a ton a mile? I believe we shall never materially improve the paying condition of our lines until we have statistics as to what it costs to haul a ton a mile. I do not suppose that the managers do not know this. Probably they have it all carefully pigeon-holed, but I think it should be made public. The Board of Trade returns give no information on this point. When we know what it costs to haul a ton a mile, we shall know what chance there is of hauling at so much less per ton per mile.

The CHAIRMAN: I am sure we are much obliged for the admirable Paper we have had from Professor Carus-Wilson, and more particularly for the remarks with which he has supplemented it, and I must ask you to join with me in passing a very hearty vote of thanks to him. (*Carried by acclamation.*)

(*The Meeting was then adjourned.*)

REPLY TO DISCUSSION, BY CORRESPONDENCE.

[Contributed by Professor C. A. CARUS-WILSON, M.A., M.Inst.C.E.]

Mr. Riches says that allowance has not been made for the increased cost due to having four gangs of men on the electric trains in place of one gang on the steam train. This is not so; the expenses in Table IV. have been worked out expressly to allow for this increase in cost, as may be seen from the text of the paper.

In reply to the criticism that there is no field of usefulness at the present time in any but suburban lines, I would point to what is now taking place in Italy. The two great railway companies there, the Adriatica and the Mediterranea, have each equipped a portion of their system electrically. The Adriatica has equipped 66 miles of existing line and the Mediterranea 81 miles. The average number of trains on these lines was about six per day; this number has been increased about three times, and the trains reduced to two cars each. The 81 miles on the Mediterranea Railway is, in a sense, "inter-urban," but certainly not "suburban," stretching from Milan to Gallarate, Varese, Levenot and Arona, while the 66 miles on the Adriatica Railway, from Lecco to Colico, Chiaveno, and Sondrio, cannot be described as other than "branch" lines.

PROCEEDINGS OF SEPTEMBER 4.

Mr. ALEXANDER ROSS, M.Inst.C.E., in the Chair.

[PAPER.]

MODERN PRACTICE IN RAILWAY SIGNALLING.

By I. A. TIMMIS, M.Inst.C.E.

THE changes which steam effected when it came into use as an aid to more rapid movement of people and material on land and water, created an ever-increasing desire and want for more perfect and faster means of effecting that movement. And now that another force of Nature, electricity, has come to the aid of steam, the growth of railways has developed enormously and the desire and necessity for intercommunication, in all countries, has not only increased but must go on increasing; as a consequence the engineers of railways are obliged to fit new signalling systems in order to deal with the larger stations, with a greater number of main lines and sidings and larger signal cabins, and the increase in number of trains and higher speeds. It has become necessary to place the points and distant signals at a greater distance from the cabins. The result of these altered conditions is that some other power is required to take the place of manual. Three new forces have been tried—*hydraulic*, *pneumatic*, and *electric*.

HYDRAULIC SYSTEMS OF RAILWAY SIGNALLING.

The experience gained from signal work operated by this force proves that it cannot compete with the pneumatic and electric systems, and so it is not advisable to take up time in describing it.

PNEUMATIC SYSTEMS OF RAILWAY SIGNALLING.

There are two systems that use air as an operating force:

(1) *The Westinghouse high-pressure.* In the first installations that were fitted in the United States, the controlling power, used was water under pressure or a combination entitled hydro-pneumatic; but as it was found that electricity was a more convenient power, it was substituted, and the present practice is called the *electro-pneumatic system.* The operating power is high-pressure air, which is conveyed in $\frac{3}{4}$-inch pipes from the main supply to the operating cylinders, of which there is one at each signal and at each pair of points. There are auxiliary reservoirs near each signal and each pair of points to collect any moisture in the air supply.

To operate a signal (Plate 3), when the lever in the cabin is pulled over; an electric current is sent to the magnet M and its armature B is attracted to it. The spindle F then closes the exhaust port and pushes the spindle S P off its seat, admitting air through E above piston P and the signal is put to "Line clear." When the electric current is broken either by a track circuit, if used, or by the signalman, B is raised by the spring round

S P, the air admission is closed and exhaust opened at H, and the signal goes to "Danger" by the counterweight.

To operate a pair of points: The chamber A receives air pressure from the main pipe, and the slide valve S controls the ports C and D admitting the air to the cylinder, whilst the port E leads to the exhaust. On each side of the slide valve chamber are placed small cylinders, V N and V R, with pistons, K and K^1, of which the rods pass through stuffing-boxes and bear against the slide valve. A passage connects the slide valve chamber A with the passage H leading into the pin valve chamber G, and therefore the latter always contains compressed air. This chamber G surrounds a small spindle valve P N, of which the prolongation bears against the spindle F of the armature of the magnet M N. The lower end of this armature spindle acts as an exhaust valve.

The magnet M R on the left side is of precisely similar construction, but the electric circuits are so arranged that when the one magnet is magnetised the other is demagnetised.

In the position shown the magnet M N is magnetised, and consequently air from the chamber G has been admitted to the space I, pushing the piston K with the slide valve S into the position shown, and thus admitting air from the chamber A through port D into the right end of the main cylinder, and placing the piston T and the points into their normal position. If now it were desired to reverse the position of the points, the signalman in the box has simply to move a lever. This movement changes the electric circuits, and an opposite set of movements are effected. In order to prevent an accidental displacement of the slide valve S, a locking pin, Q, is provided.

Air from the central chamber A finds its way through a small port under the piston M, and passes through a small hole in the piston into the cylinder end, thus equalising the pressure on both sides of the piston. The spring W then pushes the piston M down, and brings the locking pin Q into one of the recesses in the back of the slide valve S. When it is desired to release the slide valve, the magnet M L is excited by an electric current from the signal-box, and an exhaust valve, P L, is opened. The exhaust port being larger than the hole in the piston M, the excess of pressure on the underside of the piston will force the latter up, thereby releasing the slide valve S. As soon as the magnet M L is demagnetised the movements are reversed.

As soon as, and not before, the points are in their new position and locked, an electric circuit, I N or I R, is completed by the switch in box I, and an indicating current is sent to the signal-box. As long as the signalman has not received this indication he is prevented by a latch, N^2 or R^2, from completing the stroke of his point lever, and therefore he is unable, on account of the mechanical interlocking, to lower any conflicting signal until the points are properly set and locked.

In the facing point lock and detector, the sliding bar Y works the points as shown, and its end is connected by suitable cranks to either inside, Y^1, or outside, Y^2, lock-bars for facing points. Further, it not only detects and locks both tongues of the points by plungers, U^1, U^2, entering the detector bars Z Z, but the jaw X is of such a shape as to firmly lock the points in either position.

(2) *The low-pressure pneumatic* (Plate 5).—The main operating force is

air at a pressure of about 15lbs., while the controlling is effected by air at half that pressure. These pressures can be increased. All the levers are interlocked mechanically in the signal cabin by tappet locking.

When a pair of points have to be moved the signalman pulls over his lever, but only part way, against a stop, T. A valve in the cabin is opened, which is a reducing valve, U, and sends a current of air along a controlling pipe, P, to the valve R at the points. This supplies air from the main supply to one end of the cylinder, and the piston is pushed over. This operates the motion-plate, through a complete stroke, and the work done is as follows: The first portion, say one-third of the movement, unlocks the points and closes any selector ports. Then the points are pushed over, and the last third of the movement locks them again, completes and sets any selector air circuits. At the same time a return indication current is sent to the return valve in the cabin which removes the stop against the point lever and completes its stroke.

All the valves are now ready for a reverse movement. It will be seen that there are two reducing valves and two piston stops for each lever, and two valves and one cylinder and piston and five tubes for each pair of points, apart from selector tubes. In order to lower a signal, the signalman pulls his lever over to its full extent. This admits air from the main supply into the reducing valve connected with the lever, and then a controlling current is sent to one of the valves R on the signal post; this may be called the operating valve. This opens the main supply into the cylinder A. The piston is raised and the signal is lowered to "Line clear," and is held there. In order to return the signal to "Danger" the lever is pushed back and is stopped about half-way by I. Then the other controlling pipe conveys a supply of air to the other controlling valve on the post. This admits air from the main supply to the upper end of cylinder and the signal returns to "Danger" position. At the same time a return indication current is sent through the pipe to the valve in the cabin, and the stop is removed and the signal lever completes its stroke. There are two main valves and one subsidiary one and one cylinder piston at the signal post, and there is one reducing valve and a cylinder and piston in connection with the signal lever, and there are four pipes between cabin and signal.

If a track circuit is fitted, the track blocks are insulated with a primary battery in each block circuit, and at any signal that the track circuit may control an electro-magnet, which is in the circuit, controls the air valve and thus holds the signal at "Line clear" as long as it is energised; but when a short circuit is made by a train or vehicle, or the circuit is broken, the magnet is de-energised, the air admission valve is closed, the exhaust is opened, and the signal goes to "Danger." If, however, the track is empty, and lowering electric contacts are closed by a train ahead of the block automatically or by a signalman in a cabin, the signal is lowered to "Line clear."

Electric Systems of Railway Signalling.

Many systems have been tried and several have been carefully thought out and worked. One of the first that was fitted in the United States was by the Union Switch and Signal Co. The electric current was supplied from

primary batteries, and as their electro-motive force is small, and the current generated also small, it was necessary to give special attention to the design and construction of the semaphore arm and to the counterweight and general fittings, so as to eliminate friction. As a result, a light, thin, smooth arm of aluminium was adopted, with the spectacles as a counterweight. A small, low electro-motive force motor was fitted, having over 1,500 revolutions per minute, and the revolutions of the motor were as 1,080 to 1 of the semaphore shaft, or 180 revolutions to clear the signal arm to "Line clear" through 60°; this took six seconds. The motor always runs in one direction. When the signalman pulls over his lever the electric circuit is closed and a current sent to the motor, and the signal is lowered to "Line clear." This movement switches in an electro-magnet which holds the signal at "Line clear" and cuts out the motor. When the electric circuit is broken an electric slot frees the signal arm at the same time that the magnet is de-energised, and the signal goes to "Danger" automatically and instantly.

Another system fitted in the United States by the Taylor Signal Co. is entirely electrical, and both the points and signals are operated by electro-motors with secondary batteries. The whole are mechanically interlocked in the signal cabin; the rails are used as a circuit where advisable. When the signalman has to use a pair of points, he pulls his lever over and closes the circuit to the motor at the points, which revolves twenty times while the point driving-wheel is making one revolution. The first quarter of its revolution unlocks the points, and after the points are moved over the last quarter revolution re-locks them. The locking reverses the pole-changing mechanism and reverses the armature connections for the reverse movement, and also closes the return indication circuit. The power required to effect this reversing is from a coiled spring which is compressed by the locking, but is released at the end of the travel. The points are moved in the contrary direction by a set of reverse movements. The return indication current to the cabin releases the point lever and completes the freeing of the signals that may have to be lowered in connection with it.

To lower a signal to "Line clear," the lever is pulled over and a current is sent to the motor (1 to 6 H.P.). It winds up a chain which raises the counterweight and lowers the signal; as it reaches the "Line clear" position it actuates the pole-changer, switches in an electro-magnet which holds the signal at "Line clear," and cuts out the motor. When the magnet circuit is broken the counterweight sends the signal to "Danger," and restores the gearing to its normal position.

In this country the first practical electrical system was fitted to work automatically on the Liverpool Overhead Railway by the Author. The conditions which were provided for and sanctioned by the Board of Trade were:—

(1) There must always be one or more signals at "Danger" in rear of a train.
(2) It must not be possible for the signals in any block to be lowered if any vehicle of a train is left in that block or within reasonable distance ahead of the next "starter."

The signals are all operated by long-pull electro-magnets by the passing train. The points, which are only used for "cross-over" purposes, etc., and,

except at the terminal stations, are hardly ever required, are operated by means of manual power, and interlocked mechanically and electrically with all signals that either protect or conflict with them (Plate 2, Fig. 6).

As a train leaves a station the two signals "Starter" and next station "Home" must be at "Line clear." The last vehicle of the train has a striking bar, S B (Fig. 5), which operates a breaking contact, B C, close to the signal, and as the magnet is short-circuited the armature falls and the spectacle counterweight sends the signal to "Danger." Having sent both the signals to "Danger" and stopped at the next station, the train goes on to a farther station, and as it passes the "Starter" it puts it to "Danger." There are now three signals at "Danger" in rear of the train. When the train gets over a full train-length ahead of the "Starter," and it has gone to, and is, at "Danger," the striking bar on the rear vehicle closes a pair of contacts, M C, and this circuit is completed by the signal just passed being at "Danger," C C. A current goes through this circuit to the "Starter" and "Home" in the rear block, and each is lowered to "Line clear" by its electro-magnet. As the magnet attracts its armature, a switch (Plate 1) automatically switches in a resistance which reduces the lowering current of 3 to 5 ampères to 0·3 to 0·5 or 0·1, which is amply sufficient for the holding current. The cost of electrical energy with a three-minute service and for twenty hours per day is 400 × 1 second × 5 = 2000 ampère-seconds per signal, and assuming each signal is at "Line clear" 600 minutes per day, and taking 0·5 of an ampère, the total consumption at 6*d.* per kilowatt-hour for the whole railway is about the cost of one man's wages for one day.

At the Paris Exhibition, an automatic system was fitted, covering 2 miles of line (Figs. 1, 2, and 5), on the same broad lines as at Liverpool, but on a reduced scale all round. The signal arms, S, are light frames covered with red cloth and pivoted nearly at the centre of gravity. Each arm and its small magnet M, resistance, switch and contacts are enclosed in a weather-tight case with a glass in front and a lamp behind, as is clearly shown in the Cartoons. The "makers" and "breakers" are on the same principle as those of Liverpool. The electric current was from small secondary batteries, the special design of M. Lavazzari, the Honorary Secretary of the Institution of Civil Engineers of France, who is associated with the Author in all his work in France.

Another important piece of signal-work is on the Western Railway of France, close to Paris. The signals and points are worked from small levers in the cabin, and are all operated by electro-magnets. The points are locked and all repeating and selecting work done by one complete throw of a point magnet. Drawings of the arrangements are not shown, as the regulations affecting traffic in France are so widely different to those insisted on by the Board of Trade in this kingdom.

We come now to the most important of all the modern systems of signalling in this kingdom—the Crewe system, fitted at Crewe under the supervision of Mr. Webb (Plate 6).

Suppose we take one cabin containing 300 levers, or about one-fourth of all the big Crewe system. There are some 150 cables of $\frac{3}{4}$-inch diameter from the cabin, and each cable may contain 6 leads. It is quite clear that these cables, though they are placed in wooden troughs, could be supported on posts overhead. But if the low-pressure pneumatic system were fitted to the

same 300-lever cabin it would necessitate 1,200 tubes, at least, being taken from the cabin to work the signals and points, and in addition it should be pointed out that at Crewe (as at many other stations) the distant signals could not be worked by pneumatic power alone owing to the distance. Electricity would have to be employed as well owing to its inherent quickness.

The working of a pair of facing points is explained by Fig 3. The electro-motor, designed at Crewe, works in a cast-iron box sunk in the ground and in an oil bath. As the motor revolves it actuates a worm working two cam-wheels, which engage respectively with the points and locking gearing. The points are unlocked by half the throw of one rod ; then the complete throw of the other rod moves them over, and the completion of the throw of the first rod locks the points again and sends a return indication current to the cabin, which allows the completion of the movement of the point lever which was stopped when only half pulled over, and also completes the selector rod movement at the points. The trailing points are actuated by long-pull electro-magnets. The lever frame is also a special feature of the Crewe system, with tappet interlocking. The signals are operated by long-pull magnets in conjunction with resistances and switches for automatically reducing the lowering of the holding current, as already explained (Plate I.).

It is not possible in this system to lower any signal or to move any points unless the conflicting points are "right" and locked and all controlling signals are at "Danger." It will be noted that in the lever frame at Crewe there are two tiers of levers, thus reducing the size of the cabin and the work of the signalman. But there are variations which can be made by taking certain parts of systems that have been fitted and have stood the test of time and hard work, and making another combination. The following is such a one ; it is entirely electrical and can be worked either with or without a track circuit.

The description embraces a track circuit by which signals are put automatically to "Danger" by a passing train, but they are lowered to "Line clear" by the signalman and not automatically. Automaticity is perfectly easy to arrange if it is desired. All the levers in the cabin are tappet locked. Each signal is lowered by a long-pull electro-magnet as described above.

The points are worked as follows (Plate 4, Figs. 3 and 4) :—In the case of facing points, it seems better theoretically to operate the points by one pair of magnets, and the bolt and locking bar by another. Practically, however, there are objections to this, the most serious being the almost absolute necessity of having two main-current switches at the points ; this may be got over by using a separate lever in the cabin, but that entails extra expense, time, etc. I prefer, therefore, to work them by one pair of magnets of a slightly increased power over those for working trailing points. This I do by increasing the stroke to 7 inches (7 inches to 8 inches being the usual travel of a bar), which is divided up as follows : The point-lever is pulled over half-way ; the first 1½ inch of travel of the magnet moves the bar and unlocks the points, the middle 4 inches operates the points, and the final 1½ inch completes the travel of the bar and locks the points, total 7 inches. At the same time the selector bar is operated. In addition to the ordinary plunger bolt locking the two switch rails, the mechanism working the points

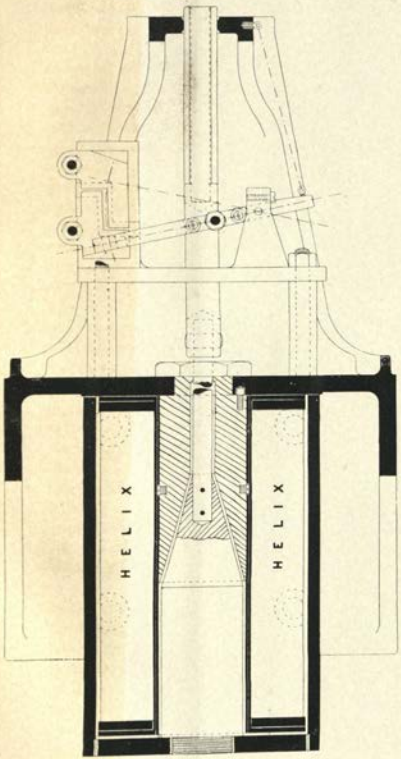
is also locked by the magnets themselves, as will be evident later. The bolt does not lock in the same notch for the different positions of the points, two notches being cut, one top and one bottom, corresponding "feathers" forming part of the bolt engaging with them, and making the lock. The whole travel of the magnets is communicated to the bar and bolt. Thus it will be seen that the magnet exerts its force only on the bar and bolt at the commencement, when the bar requires most force to lift it. When the bar is partially lifted, and consequently requires a considerably diminished force, the magnet takes up the movement of the points.

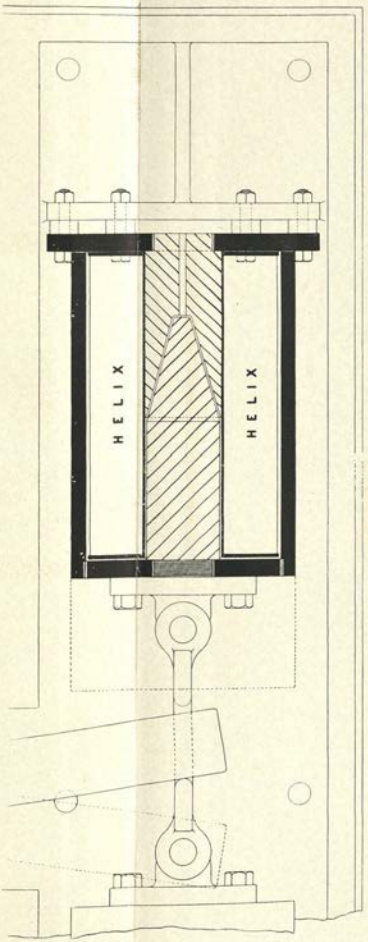
The method of conveying the movement to the points is by means of the well-known tumbler and jaw type. The link connecting the two magnets engages with the tumbler at T. The first movement (namely, 1½ inch) of the tumbler unlocks the jaw J. It then moves it over (4 inches) and finally locks it again. The jaw forms part of a bell crank, the other arm of which is arranged to give an adjustable throw. This is very necessary for accurate working, as the slightest wear or movement of the stock rails should at once be provided for; if cranks of set length or motion-plates cut out of the solid are used, no adjustments can afterwards be easily made. The bolt and bar are fitted with detectors for conveying the return current to the cabin, and this completes the movement of the lever. By an air-cushion arrangement to the magnets, the blow usually associated with magnet-operated mechanism is practically eliminated.

It should be carefully pointed out here that there have been many complaints made, in connection with electrical fittings, of leakage, short circuits, etc. The reasons for these complaints are quite clear: Improper and insufficient insulation, flimsily made contacts, and so forth. It has been stated in print that induction currents have a serious effect on electrically-worked signals and points. But it must be asserted in the plainest language that neither induction currents nor the most violent atmospheric electrical disturbances affect a current of 50 volts or over, having a volume in accord with the resistance of the conducting lead $\frac{E}{R} = C$; and as regards the insulation and fitting of leads, and the designing, making, and fitting of contacts and switches, if the same care and thought are taken about them that are taken in the making and fixing of hydraulic and pneumatic gearing, there is less risk with the electric gearing, and on the other hand there is more certainty of its working properly than with hydraulic or pneumatic arrangements.

Then as to quickness. There is no force in Nature which is so instantaneous in its action as electricity, or so amenable to the varied wants for which it may be used. Consider the present question of operating signals and points. It takes considerably less than a second to lower a signal or to move and lock a pair of points by electro-magnets, and the total time taken to complete an operation including the return indication current is far less than that taken by any other force. This is a known and proved fact. Pneumatically-worked signals at 500 yards distance take 9 to 10 seconds to complete the return current, and it is not practicable even if it is possible to work signals at 1,200 yards (and it is often advisable to increase that distance) by any power except electricity.

EARLS COURT ELECTRIC SYSTEM. Nº I.





L.O.R^Y. AND PARIS AUTOMATIC ELECTRIC SYSTEMS. Nº2.

FIG 1

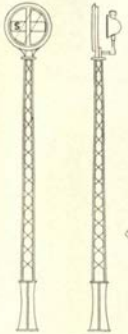


FIG 2.

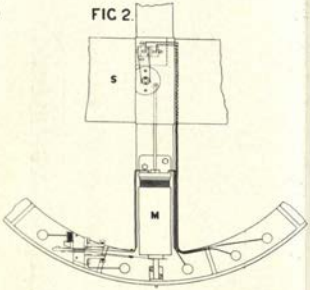


FIG 3

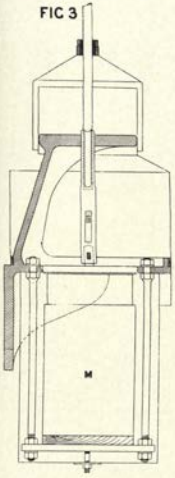


FIG 4

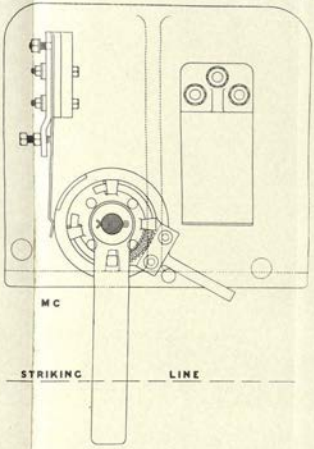


FIG 5.

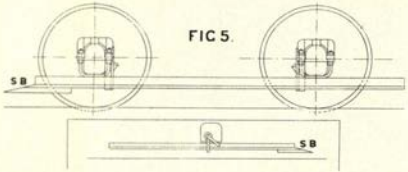
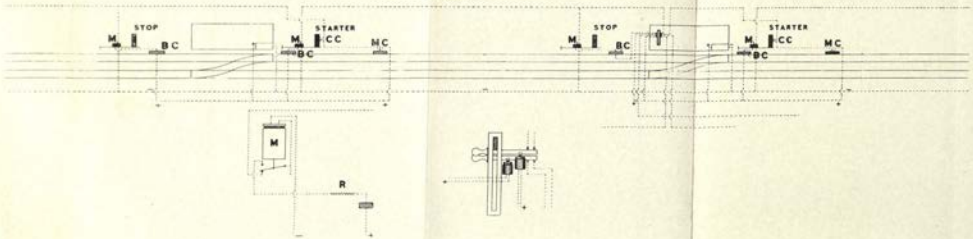
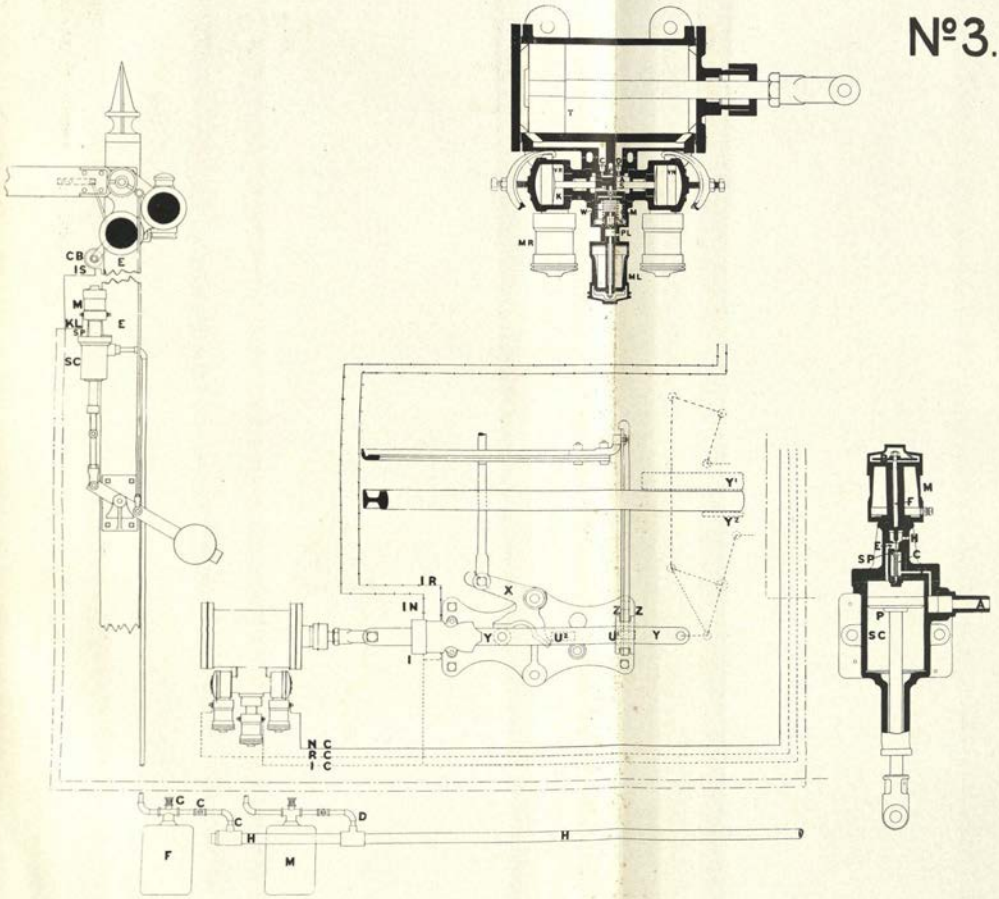


FIG 6.



WESTINGHOUSE HIGH PRESSURE PNEUMATIC ELECTRIC SYSTEM.

Nº3.



COMPLETE ELECTRIC SYSTEM.

Nº4.

FIG 1.

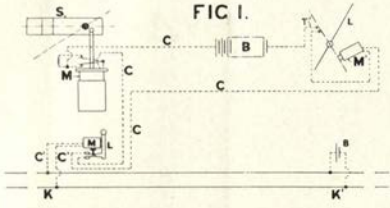


FIG 2.

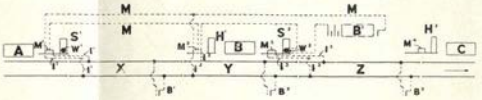


FIG 3

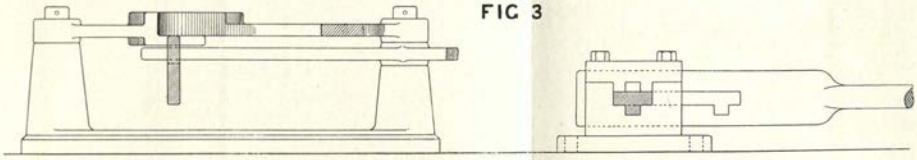
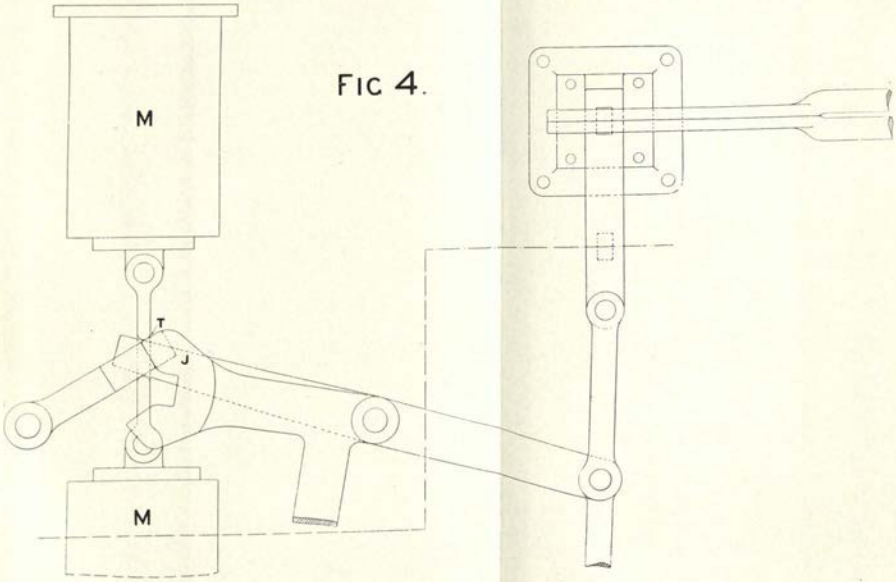
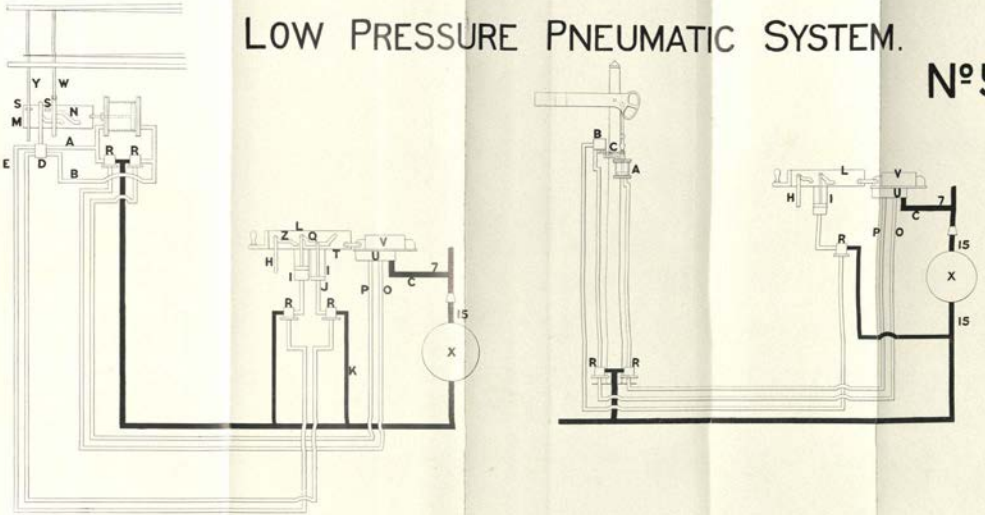


FIG 4.



LOW PRESSURE PNEUMATIC SYSTEM.

Nº 5



CREWE ELECTRIC SYSTEM. Nº 6

FIG 1.

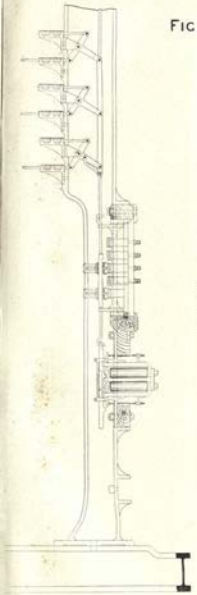


FIG 2.

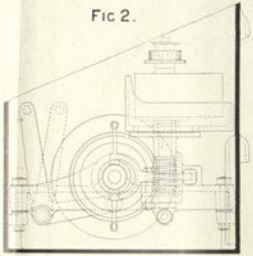


FIG 3.

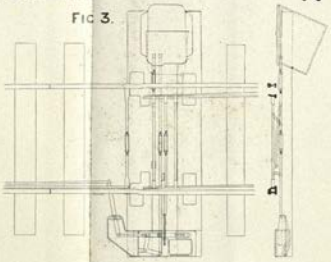


FIG 4.

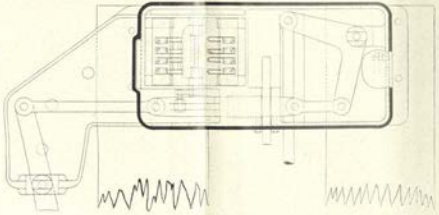
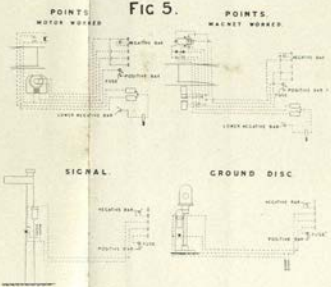


FIG 5.



DISCUSSION.

The CHAIRMAN: Gentlemen, I feel we must all agree that Mr. Timmis has given us a very clear, concise, and I may say a very impartial description of the various power signallings, which are very much before railway engineers at the present time. We gather, however, that his predilections lie with the purely electrical system. I am not going to take up the time of the meeting by saying anything more; the subject is before you. Probably representatives are present of each class of signalling which has been described, and we shall be glad to hear their views.

Sir DOUGLAS FOX: I should not like this Paper to pass *sub silentiæ*, because we are indebted to Mr. Timmis, not only for his very carefully prepared paper, but far more for his untiring efforts to perfect this system of electric signalling.

At least eleven years must have elapsed since I first had the pleasure of discussing the subject with Mr. Timmis; and it is about nine years since, under my advice, his system was put into actual practice in connection with the Liverpool Overhead Railway. At that time very little was known as to what the result would be; but it was felt that on that railway—where no shunting was done except at the two termini—there was an excellent opportunity of testing the applicability of electricity by means of magnetism to the operation of signals. The Board of Trade were at first very properly cautious as to sanctioning this process; they required regular returns of the extent to which the system failed to act. Of course every failure meant a delay of traffic, because the signals were always at danger. There were at first minor difficulties in detail, simply in connection with the action of the magnets, and by degrees experience was gained; but I may say, speaking on behalf of the company, that the signals of intermediate stations, of which there are twelve, have given great satisfaction, and the result has been a saving in the employment of twelve signalmen during the whole of that time. The system, as applied there, is very simple; Mr. Timmis has already explained its action. I did not feel justified, under the existing conditions of knowledge in this matter, to authorise the introduction of the electrical system at the termini, where there is a certain amount of shunting to be done, and where it was necessary to introduce the human brain as a directing power.

We are very much indebted to Mr. Webb, in that he has worked out this system at Crewe, and shown how it can be applied on a very extensive scale to shunting operations, and to dealing with the signalling in large stations. It seems to me that this system has a great future before it. I cannot myself believe that the low-pressure pneumatic system can come into anything like serious competition with electrical signalling in the end, because it necessitates a large number of pipes; and pipes are much more likely to get out of order and entail expensive repairs than electrical conductors. How far the Westinghouse high-pressure system can be successfully dealt with, operated as it is by electricity, is a matter which will be of

great interest to all railway engineers. But I am quite convinced that, with reference to underground railways where electricity is installed for traction purposes, the electric system presents very great advantages. We have not experienced, since the system has had a little life put into it and has been improved in certain details, all the difficulties which have been spoken of, either as regards leakages or the effects of induction; and I should think that the Liverpool Overhead Railway would have brought out very strongly that last evil had it existed, because it is worked electrically, and our electrical conductors are in close juxtaposition to the feeders which operate the signals. We are indebted to Mr. Timmis, who I hope will be successful in working out this very important innovation in railway signalling.

Mr. F. W. WEBB: I had not intended to take part in this discussion, and I was not aware, until I came into the room, that Mr. Timmis had given such a complete illustration, and I may say impartial description, of what has been done at Crewe. We have to thank him for allowing us to use the long-pull magnet which we employ for the signals and for some of the shunting points, in connection with the work we have carried out there. I think he will agree with me that the whole of the details of the Crewe installation have been worked out by ourselves; I rather gathered that Sir Douglas Fox was under a different impression. So far as we are concerned, we do not require the track system. It would not be applicable to a large station with crossings from one line to another, because the points themselves cross over roads which have to be worked automatically, in connection with the electric system. At Crewe, where we have lately put down about fifty miles of shunting sidings for exchanging wagons on all parts of the system, the whole of the signalling and points are worked electrically in the manner described. When the passenger station is completed, I trust that there will not be a single wire or point-rod to be seen on the ground. The whole of the work will be done electrically, and as Mr. Timmis indicated. We are now at work making the cabins, which contain 300 levers, to control the whole of the north end of the passenger station. It is two and a half years since we opened the first main-line junction at Crewe with this system and the motor-worked facing points; and up to the present time it has given entire satisfaction, and caused fewer delays in the traffic than any other system we have. Of course since it was first adopted we have considerably improved the small details of the levers and lockings, and now I think it as perfect as it can be. I am glad of having had the opportunity of making these few remarks. I have nothing further to add, except that I shall be glad to answer any questions members may desire to ask.

Mr. W. B. WORTHINGTON: I shall be glad if any gentleman present can tell us what are the advantages of the low-pressure pneumatic system. It seems quite clear that a system which requires to have four pipes to every signal and, if I am right, five pipes to every pair of points, must be difficult to work in a complicated yard, and must be difficult to maintain. I am aware that it has been adopted in complicated yards, for instance, at the New York terminus of the New York Central Railroad, where it has been recently put down, and is now in operation. It seems so clear, however, that the four long lines of pipes going to distant signals must be a very great disadvantage as compared with the electric wire; and I had hoped, as the subject was brought

forward by Mr. Timmis, that we should have heard, from the pneumatic side, some reasons why that system is recommended for adoption. It has been experimentally adopted on a considerable scale by a large company in the south, and if any gentleman present can tell us its advantages it would be of great help to some of us who are seeking improved methods. My own company is about to put down a trial installation on the electro-pneumatic system, where we have special power facilities; and I would like to hear what is to be said for the low-pressure system.

The CHAIRMAN: I am afraid there is no low-pressure champion here, but if there is we shall be glad to hear him. I must now call upon Mr. Timmis to reply to the remarks that have been made.

Mr. I. A. TIMMIS: I do not think that there is anything to reply to on my part, except to thank Sir Douglas Fox and Mr. Webb for their remarks. It was a great pleasure to me to act as I did under Sir Douglas Fox's advice, some years ago, at Liverpool, and it has been, of course, a matter of great satisfaction to see what Mr. Webb has accomplished at Crewe. The system there is, in my opinion, all that is required, and I have great pleasure in mentioning the name of Mr. Thompson, who, as most railway men know, is the signalling superintendent of the London and North-Western Railway at Crewe, in connection with the work. Those who have known Mr. Webb, as I have had the pleasure of knowing him, for a period of thirty or forty years, look upon him as the London and North-Western Railway; we mention Mr. Webb, and there is an end of it. With regard to Mr. Thompson, I have come across few men in electrical engineering work who are more solid, thorough, and cool than he; those who know him and Mr. Webb know the implicit confidence Mr. Webb places in him, and he is worthy of it.

I am sorry no one is here to take up the cudgels on behalf of the five and four pipe movements. A short time ago I happened to be at Crewe and asked Mr. Webb a pertinent question. It was, "Can you tell me how many pipes would be necessary in the 300-lever cabin at Crewe, supposing you fitted up the low-pressure pneumatic system?" He replied, "I will not give you my own figures, but I will give those of the low-pressure representative. There would be 1,200 tubes." I have made my own calculation, and feel perfectly certain they could not carry out the work there even with 1,200 tubes.

The CHAIRMAN: It only now remains for us to pass a vote of thanks to Mr. Timmis for his very able, clear, and instructive Paper, and I have pleasure in proposing it. (*Carried by acclamation.*)

REPLY TO DISCUSSION, BY CORRESPONDENCE.

[Contributed by I. A. TIMMIS, M.Inst.C.E.]

The main end in adopting a new system of railway signalling must be economy; efficiency is included, otherwise there is no economy. A railway system, so far as signalling is concerned, should be divided under two heads:—

(1) Termini and junctions. (2) Small through stations.

One great expense is the labour attaching to and the upkeep of signal cabins. These will never be got rid of at large stations, but there is no necessity for them at small through stations.

Automatic working of electrically operated signals has been demonstrated for several years at Liverpool and in Paris, as described in the Paper; and Sir Douglas Fox's comments on the saving of labour are conclusive. Points are only used at small through stations for special shunting, and can be worked by manual power—there is no reason against this—from a small lock-up box or room by the station-master or head porter, the points and signals being mechanically and electrically interlocked. Furthermore, automatically worked signals at small stations can be worked from primary batteries with or without a track circuit; a system on these lines would deal effectually with the whole of a railway excepting junctions and termini, and at a small cost. There is no need for any electrical generating plant except at large stations; but where signal cabins and men are necessary it is an economy to have an electric generating plant for lighting. In this case the electricity consumed to operate points and signals, as is proved by work and by calculation in the Paper, is hardly felt.

The particulars given in the Paper of installations in regular work prove that the most economical system is that which operates, controls, and repeats all signals and points by electro-magnets off the lighting circuit at large stations, and the signals at small through stations by electro-magnets automatically by a track circuit or otherwise. In the case of electric railways the magnets can be wound to work off the main circuit.

Sir BENJAMIN BAKER, K.C.M.G., D.Sc., LL.D., F.R.S., in the Chair.

[PAPER.]

SUDAN GOVERNMENT MILITARY RAILWAYS.

By Major C. B. MACAULEY, R.E.

IN considering this Paper the following points should be borne in mind :

(1) The line was laid primarily to supply an army in the field, the route, method of laying, and material being all chosen with this object in view.

(2) Partly as a consequence of (1) nearly fifty per cent. of the line is laid in desert.

(3) Every train leaving one terminus for the other has to take nine thousand five hundred gallons of water with it, to enable it to cross the waterless desert sections. This water is carried in special tank trucks, five of which are required in addition to the tender ; it will be readily seen that this considerably diminishes the useful carrying power of the line.

The Sudan Railways consist of two branches ; both start from Wadi Halfa.

One goes to Khartoum, a distance of 576 miles by rail, and the other to Kerma (in the Dongola Province), a distance of 203 miles by rail. (*See sketch map.*)

It will be most convenient to consider each branch separately, as they run through different kinds of country.

GENERAL DESCRIPTION OF THE KHARTOUM LINE.

The Khartoum line leaves Wadi Halfa and goes in a south-easterly direction through the Nubian Desert to Abu Hamed, which is 230 miles from Wadi Halfa. The whole of this part of the country is a flat sandy desert ; occasionally a few hills are seen, but they seldom exceed 300 feet in height, and most of them are only from 80 to 100 feet above the surrounding country. Some idea of the extraordinary flatness of the country may be gathered from the fact that it was possible to lay a piece of line 45 miles long without a single curve in it, and without any cuttings or embankments worthy of the name.

It very rarely rains at all in this part of the desert, and when it does very little seems to fall at a time. There are no streams or surface water of any sort. Water was found in two places between Wadi Halfa and Abu Hamed by sinking wells ; one place was 77 miles and the other 126 miles from Halfa. Water was found at the former place at a depth of 72 feet, and at the latter place at a depth of 96 feet. Several other places have been tried, but so far no water has been found.

The only vegetation in this part of the country consists of a few Sunt trees, a kind of acacia ; there are extremely few of them. Their presence does not seem to indicate the presence of water at any reasonable depth, as.

although they exist at both the places where water was found, they also exist at places where water could not be found at a depth of 200 feet. Occasionally just after rain a coarse grass springs up, but it soon dries up again and disappears.

There are nine stations, for crossing trains, in this section of the line. At No. 6 station (126 miles from Halfa) there are small shops and an engine pit. At Abu Hamed (230 miles from Halfa), where the line comes down to the river again, there is a running shed for eight engines, with a small workshop containing a few lathes and drilling machines, etc. From Abu Hamed to Shereikh (292 miles from Halfa) the line runs close to the river; the country here consists of small sandy hills with rock cropping up occasionally; limestone and mica are found here, but the latter is in too small pieces to be of much use. Date palms and dôm palms are plentiful, and there is a certain amount of cultivation, which is increasing as the people come back to their villages, from which they had been driven by the dervishes. At Shereikh the line leaves the river again and makes a detour into the desert in order to avoid a very rough, rocky bit of country; in this part, as in most parts of this country, it appears to be a maxim that flat ground can always be found by going far enough from the river. The line comes down to the river again at Abadia (340 miles from Halfa).

At Abadia there are small workshops and a couple of engine pits. From Abadia the line runs along near the river over a flat plain covered with scrub, the soil being something like cotton soil. There are old native salt workings here.

The next place of any importance is Berber (362 miles from Halfa). This is by far the largest place on the railway between Halfa and Khartoum. From Berber the line runs over the same sort of plain to the Atbara River (385 miles from Halfa). The line crosses the Atbara at a point about half a mile from its mouth. The bridge is 1,050 feet long, consisting of seven spans of 150 feet each. The girders are supported on pairs of cylinders sunk into the bed of the river and resting on rock. During the construction of the line, before the permanent bridge was completed, a wooden pile bridge was used. From the Atbara the line runs more or less parallel with the River Nile, and at a distance varying from a few yards to four miles from it, through a country which consists chiefly of a flat plain covered with scrub and small trees. The scrub is very thick, in some places too thick for a man to force his way through, but this is only in some of the watercourses. The plain extends, as a rule, for a distance of two to three miles from the river; after that rocky hills begin. In some places the hills come down almost to the river, whilst in others the plain stretches as far back as can be seen, rising gently as it gets further from the river. The plain is intersected by watercourses, dry for the greater part of the year, but which are liable to be flooded in the rainy season. South of the Atbara River rain falls every year. The line has very few bridges or culverts at present, and, as a consequence, is often washed away in places.

At the speed at which the line was laid, about two thousand to two thousand eight hundred yards a day, with a maximum of five thousand one hundred yards in one day, it was impossible to build bridges or culverts; this defect is now being remedied as quickly as possible. White ants are present in considerable numbers on this part of the line, and steel sleepers are neces-

sary. The whole country, from the Atbara to Wad Ben Naga (496 miles from Halfa), practically answers to the above description. There are many villages along the river banks, and a considerable amount of cultivation. The inhabitants own large numbers of cattle, sheep and goats. The usual date palms and dôm palms are found on the river banks.

The stations are: Ed Damer (392 miles from Halfa), Zeidab (399 miles from Halfa), Mukhmir (430 miles from Halfa), Kobashieh (451 miles from Halfa), Shendi (471 miles from Halfa). At Shendi are workshops, engine pits, and reserves of coal and stores generally. It is, from the railway point of view, the most important place on the line next to Wadi Halfa. It is situated almost in the centre of the Atbara-Khartoum section, and being liable to be cut off from Halfa for periods of several days during the rainy season, it has to be self-contained. At Wad Ben Naga (496 miles from Halfa) the line leaves the river again and goes through the desert to Wad Ramleh station, near the large village of Gehli, Zobeir Pasha's village (545 miles from Halfa). By taking this route the line cuts off a corner, and avoids the rocky bit of country which exists on each side of the Shabluka cataract. From Wad Ramleh station the line runs parallel to the Nile and about two miles from it to Halfaya station, the terminus, a point on the Blue Nile about a mile from its mouth and exactly opposite Khartoum. The country between Wad Ramleh and Khartoum is a flat plain. The soil is like cotton soil, on which the natives grow large quantities of dhurra after the rains. There is a certain amount of scrub near the river, and there are several large villages on the river banks.

General Description of the Kerma Line.

The line to Kerma runs south from Halfa, following the course of the river as far as Sarras (33 miles from Halfa). The country for the first five miles is a flat sandy plain, but after that, where the second cataract begins, the country changes to low rocky hills with very little soil of any sort. The cuttings and embankments in this section are the largest on the line, some of the cuttings being 40 feet deep through rock. This part of the railway was made years ago, and the work on it generally is far heavier than on any other part of the line. It could not have been done during the hurry of an expedition. The gradients are frequent and as steep as 1 in 60. The curves also are numerous and sharp, 500 feet radius being the sharpest. There are twenty-four bridges on this section, most of them being iron-plate girders with stone abutments; the largest is 100 feet long, in three spans.

At Sarras the line leaves the river and winds in and out among rocky hills, chiefly following dry watercourses, to Akasheh (86 miles from Halfa). There are two stations for crossing trains between Sarras and Akasheh, one at Moghrat (47 miles from Halfa), and one at Ambigole Wells (64 miles from Halfa). At this latter place there is a good and constant supply of water from three wells, 25 feet deep. At Akasheh the line comes down to the river, but leaves it again at once and goes through rocky country to Ferket (99 miles from Halfa), where it again comes down to the river. The whole of the country from Sarras to Ferket is one mass of black rock. The railway winds through it in an extraordinary way to avoid cuttings and embankments as far as possible; the result is that there is hardly a straight

or level bit of line in this section, which is more an example of what can be done by a good survey than of what a railway ought to be.

Owing to most of this part of the line being laid in watercourses, it is liable to be washed away for considerable distances at times; fourteen miles were washed away during the 1896 expedition, and smaller portions have occasionally been damaged since. The cost of laying a safer line would, however, be so great, that it has been considered better to take the risk at present than to attempt it, especially as it rains very rarely in this part of the country. Some more bridges and culverts are, however, to be built.

From Ferket the line runs along the river bank to Kosheh (105 miles from Halfa). The nature of the country changes again here, and it is once more a wide sandy plain, with a considerable amount of cultivation and date palms along the river banks. At Kosheh there is a small running shed and workshop. There is a considerable trade in dates from this place during the season.

From Kosheh the river makes a large bend, and the railway leaves it and goes across the desert to Dulgo (174 miles from Halfa). There is a station for crossing trains half-way between Kosheh and Dulgo. This bit of desert is fairly flat. There is one bridge in this section, about eight miles from Dulgo. It is built over a watercourse named Abu Sunt, down which a considerable quantity of water comes at times. The bridge is 200 feet long, seven spans, brick arches. At Dulgo the line comes down to the river again. There is a good trade in dates from Dulgo. Both the Kosheh and Dulgo dates are considered to be the best in the Sudan, and fetch good prices.

From Dulgo the line goes along the river bank for about ten miles. At this point the river makes a considerable bend, and the railway leaves it and, cutting off a corner, runs across the desert to Kerma (203 miles from Halfa). Kerma is situated in the middle of a large flat plain, with dark soil something like cotton soil. It is very fertile, and is cultivated in places at a considerable distance from the river. Kerma itself is a large village, a little south of the railway terminus. At the terminus there is a small running shed and workshop. Kerma is the starting place of the steamers for Dongola. Considerable quantities of dates and grain come down by rail from Kerma, also a small quantity of ostrich feathers.

Details of the Khartoum and Kerma Lines.

Permanent Way (*Khartoum line*).—Single line: gauge, 3 feet 6 inches. Rails: Vignoles section, 50lbs. per yard. Sleepers of three kinds: creosoted wood, uncreosoted wood, and steel, 81lbs. The rails are fastened to wooden sleepers by spikes (no bearing plates) and to steel by keys. Joints: one flat and one angle fishplate. The line is unballasted except in a few places; arrangements are being made for ballasting.

Permanent Way (*Kerma line*).—Single line; gauge 3 feet 6 inches. Sleepers: pine. Rails vary, some 41¼lbs., some 36lbs., some 50lbs.; the older sections have the lighter rails; all are Vignoles section, and are fastened to sleepers by spikes without bearing plates. Joints: two flat fishplates on older sections, one flat and one angle on newer sections.

Bridges.—Very few in existence. All except the Atbara bridge are steel-

plate girders ; 50 feet and 30 feet lengths are used, one or more spans being employed as may be necessary. More bridges are now being built. Rails are laid on tops of girders.

Culverts.—Owing to the lowness of the embankment in most places these are all small, the most convenient type being cast-iron pipes two feet in diameter, several pipes being used if necessary. They are set in masonry, with an apron on the down-stream side of the embankment to prevent scouring away the foot of the bank.

Gradients.—The steepest gradient on the Khartoum line is 1 in 120. From Wadi Halfa to No. 5 station is the heaviest pull on the line; it is uphill practically the whole way. Wadi Halfa is 446 feet and No. 5 is 2,010 feet above mean sea level. The line falls again from No. 5 to Abu Hamed (1,200 feet above mean sea level) ; after this there are no very long gradients. The line between Abadia and Shendy is practically level.

Curves.—The sharpest curve on the Khartoum line is 955 feet radius; there are very few as sharp as this, the usual being 2,865 feet radius.

Stations.—Most of these are at present rather primitive, but they serve their purpose. At Halfaiya, Shendi, and Halfa there are proper stone and burnt-brick buildings; at all other places buildings are of sun-dried brick. The following stations are the only places where there are loops for crossing trains : Nos. 1, 2, 3, 5, 7, 8, 9, Dekheish, Abu Dis, Abu Sillem, and Berber South, Ed Damer, Zeidab, Kobashieh, Wad Ben Naga, Gebel Gerri, Wad Ramleh. Engines can water at Halfa, No. 4, No. 6, Abu Hamed, Shereikh, Abadia, Atbara, Mukhmir, Shendi, Wad Ben Naga, Halfaiya; engines can coal at Halfa, No. 2, No. 4, No. 6, No. 9, Abu Hamed, Abu Dis, Shereikh, Abadia, Atbara, Mukhmir, Shendi, Wad Ben Naga, Wad Ramleh, Halfaiya. There are no turntables on the line, triangles being used; these exist at Halfa, No. 6, Abu Hamed, Abadia, Shendi, Halfaiya.

On the Kerma line, the stations are of simple construction, with loops and sidings according to their traffic requirements. Engines can water at Sarras, Ambigole, Akasheh, Kosheh, Dulgo and Kerma. There is a reserve of coal at every station. There are triangles at Akasheh, Kosheh and Kerma.

Workshops.—The main workshops are at Wadi Halfa ; these consist of—

(i) Running shed holding twelve engines.

(ii) Erecting shop for heavy repairs, holding nine engines.

(iii) Smiths' shop containing twelve smiths' hearths, coppersmiths' hearths, steam hammer, punching and shearing machine, plate-bending machine, radial drilling machine.

(iv) Machine shop, containing wheel lathes, screw-cutting lathes, slotting machines, shaping machines, planing machines, slot-drilling machine, drilling machines, milling machine, emery polishing machine ; all the above being driven by a horizontal compound engine, 45 indicated horse-power, the steam being provided by two Lancashire boilers, one in use at a time.

(v) Foundry for brass and iron castings up to $\frac{3}{4}$ ton.

(vi) Yard where boiler-work is done (shop to be built here) ; with overhead crane on gantry, 15 tons lift ; and tyre furnace for shrinking on tyres, also used for case hardening.

(vii) Carpenters' shops, containing two circular saws, one general joiner, two wood-drilling machines, one wood-turning lathe (pattern-maker's) ; all

driven by a locomobile engine. Much of the wood-turning is done by local men, who use an arrangement of their own. The work is held between two mandrils, the chisel between the man's toes, and the work is turned by an object like a bow, with the string twisted round the piece of wood in hand. There is one large shop for carpenters, besides the machine shop, and also a small shop for pattern-makers' work.

(viii) Carriage-repairing shops, consisting of two shops 100 yards long, with two lines running down each, fitted with benches, etc., for fitters at the sides; two overhead gantrys, with differential pulleys, for lifting trucks rapidly. All repairs to rolling stock are done here.

There are also sheds for heavy smiths' work in connection with such things as truck frames, etc. There is a small shed for smiths and fitters at No. 6 station.

Abu Hamed has a running shed, capable of holding eight engines; also some lathes and drilling machines, engine pits, stores, etc. Abadia has a fitters' shop and smiths' shop, also two engine pits and a small store. Shendi has shops which are next to Halfa in size; also a running shed capable of holding six engines, fitters' shop, wheel and screw-cutting lathes, drilling machines, slotting and shaping machines, smiths' shop, reserve stores of coal, etc. Halfaiya has no shops of any importance, but only a few fitters, carriage examiners, etc.

On the Kerma line there are small workshops at Kosheh and Kerma.

Locomotives.—The engines on the Khartoum line are heavier than on the Kerma line. There are seven classes. The number of classes is due to the rapidity with which the line was laid; engines had to be obtained somehow at once, and we sometimes had to take whatever we could get the soonest.

There are eight Neilson's engines, same pattern as supplied to the Bechuanaland Railways: eight-wheel coupled, leading four-wheeled bogie; cylinders, outside, 17 inches by 23 inches; driving wheels, 3 feet 6 inches diameter; weight on driving axles, 9·2 tons each.

There are five Hunslet Co.'s engines: six-wheel coupled; leading and trailing pony truck; driving wheels, 3 feet 6 inches diameter; weight in working order, 37 tons; outside cylinders, 14 inches by 20 inches; Walschaert's valve gear. These engines take the same train over the flat section, from Abadia to Shendi, as the Neilson's take over the more hilly section, between Halfa and Abadia.

There are two Dübs' engines, same as supplied to Natal Railways: eight-wheel coupled; driving wheels, 3 feet 3 inches diameter; leading four-wheeled bogie and trailing pony truck; side tanks; outside cylinders, 17 inches by 21 inches; weight in working order, 50 tons.

Three Hunslet's similar to five mentioned above, but with eccentrics instead of Walschaert valve gear.

Six engines by Manning, Wardle and Co.: six-wheel coupled, leading and trailing pony trucks; outside cylinders, 14 inches by 18 inches; Walschaert valve gear; weight in working order, 31½ tons.

Eleven engines of the Mogul class, by the Baldwin Locomotive Co.: six-wheel coupled; driving wheels, 4 feet diameter; outside cylinders, 17 inches by 24 inches stroke; leading pony truck; bar frames; weight in working order, 38 tons.

Four engines by the Baldwin Locomotive Co.: four-wheel coupled; leading four-wheeled bogie; driving wheels, 5 feet diameter; outside cylinders, 15 inches by 24 inches; weight, 31 tons. These are used for the faster light trains.

Two Beyer Peacock's engines: six-wheel coupled; driving wheels, 3 feet 6 inches diameter; leading pony truck; saddle tank; outside cylinders, 14½ inches by 22 inches. In addition to the above, there are two shunting engines, both four-wheel coupled, by Neilson and by Black, Hawthorn & Co.

On the Kerma line, owing to the light rails and bridges on its older sections, and also to its sharp curves, one class of engine only is used—a four-wheel coupled side-tank engine, with leading four-wheeled bogie; driving wheels, 3 feet 9 inches diameter; outside cylinders, 14 inches by 20 inches; weight in working order, 30 tons. There are six of these engines, which were made by the Hunslet Engine Company, Leeds.

Passenger Stock.—This has hitherto consisted of six saloons of the Indian type. Two trains *de luxe* with sleeping and dining cars are now being bought and some spare cars as well. There are fourteen so-called passenger carriages now, but they are of a rough description and will be done away with when the new stock arrives.

Goods Stock.—Double bogie trucks, 32 feet over all, by Messrs. Brown, Marshall & Co.: fifty-seven 10-ton trucks—some of these have been fitted as cattle trucks—sides 3 feet 6 inches high; one hundred and twenty-three ditto, sides 1 foot 6 inches high; ten 14-ton covered trucks; thirty-six 12-ton covered trucks; six brake vans.

Four-wheel trucks by Messrs. Brown, Marshall & Co.: one hundred and three 5-ton trucks; eight cattle trucks; eight high-sided trucks, sixteen brake vans. Twenty-two four-wheel trucks by Cochrane & Co.

System of Working.—The line is worked on the absolute block system—no proper block instruments have yet been provided. Telephones are used. There are no safety appliances, such as facing point bolts, or points interlocked with signals and one another, etc., etc. The question of providing these is now under consideration.

Service of Trains.—The ordinary service of trains to Khartoum consists of two fast trains weekly each way (connecting with the two principal mails from and to north) and one slow train each way daily. The latter, although it carries passengers, is really a goods train, and carries to south all Government supplies, stores, building materials, etc., bringing back chiefly gum, also a certain amount of ivory, senna, ostrich feathers, and grain. The service to Kerma consists of two mail trains each way weekly, connecting as above with the European mails, and other trains as may be required, usually three or four a week each way, making a total of five or six trains each way weekly. A good deal of grain for the army at Khartoum is brought from Kerma, and in the date season a certain number of special trains are run to accommodate the date merchants. In addition to the above there are a considerable number of trains at work on the improvement of the lines generally.

Stores.—The bulk of the stores for the line are kept at Halfa. Coal is stacked in the open.

The stores are divided into three divisions: (i) Expendable stores, such

as coal, oil, waste, and materials for use in shops generally; (ii) tools; (iii) spare parts of engines and machines.

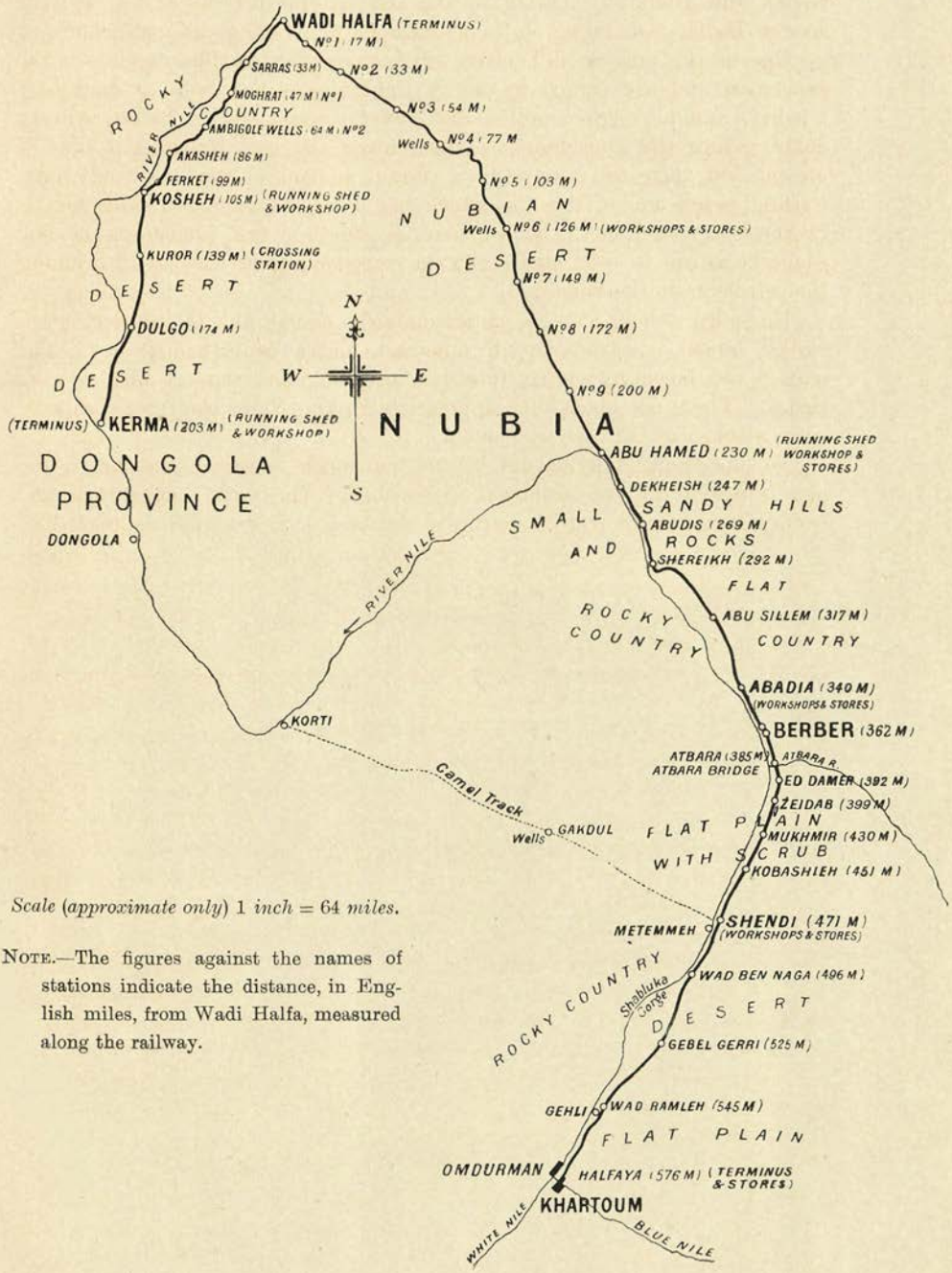
There are small expense stores at No. 6 station, Abu Hamed, Abadia, Shendi and Halfaiya. Owing to the cost of transport all stores are very dear at Halfa, coal costing on the average £3 a ton and occasionally more.

One of the greatest difficulties which has to be contended against is the great wear and tear caused by sand. Engine tyres wear with extraordinary rapidity, and all engine motion also suffers considerably. Ballast will no doubt reduce this considerably by preventing the sand flying as it does at present, but there will always be a certain amount of sand on windy days. Putting petroleum on the line, which has, I believe, been tried with success in America, would be of no use here, as after the first sandstorm the line would be as bad as ever, apart from the consideration of the cost of bringing the petroleum to the Sudan.

Unskilled labour can be obtained fairly easily, but is not very good. Skilled labour is at present all imported, and is consequently dear. The natives are, however, coming forward fairly well, and show a wish to learn trades. There are about fifty apprentices in the Halfa workshops learning various trades at the present moment.

To sum up generally it must be said that much remains to be done to the line before it can be considered as finished. The work, however, is now being taken in hand, and in the course of a year or so should be completed.

SKETCH MAP OF THE SUDAN GOVERNMENT RAILWAYS.



Scale (approximate only) 1 inch = 64 miles.

NOTE.—The figures against the names of stations indicate the distance, in English miles, from Wadi Halfa, measured along the railway.

DISCUSSION.

The CHAIRMAN: It is to be regretted, of course, that the Paper is not illustrated, either by diagrams or by lantern slides, but I ought to explain that the origin of the Paper was really no burning desire on the part of Major Macauley to write it, because no one was more surprised than he when he got the request to do so at Khartoum. It originated on the side of the Committee of this section, who thought that as the Sudan Railway had been so prominently before the public for some years, it was rather remarkable that no authoritative description had been set down by any of the engineers employed on it. Therefore I wrote to the Minister of Public Works in Egypt, asking him whether he could manage to get something for this section. He said that as Colonel Girouard had gone to South Africa, Major Macauley would be the best man to do it, and it was really a good-natured action of Major Macauley to respond to the request of the Committee. I am sure no further apology is necessary for the absence of diagrams and lantern slides.

The Sudan Railway, I think, was first prospected about the year 1865 by the late Mr. Walker, the contractor of the Manchester Ship Canal, the Severn Tunnel, and many other great works. He went out with an expedition and choose a route, not the one described in this Paper; but some years afterwards, when Ismail was Khedive, he asked the late Sir John Fowler to sent out another expedition and study the question in greater detail. The Sarras branch is the first part of that railway, which had to be abandoned in consequence of the financial disasters which overtook Egypt at that time. The scheme was not revived again until the time of the Gordon Relief Expedition, and then Lord Kitchener and his adviser—Lieutenant Girouard, as he was then—saw that it was impossible to carry the line along the river and cross Bayuda desert, but found another route across the desert. One man at least, namely Girouard, has made his reputation by that work. He was, after its completion, made chief of the Egyptian railways, and then went with Lord Kitchener to South Africa to organise the very important railway arrangements there; and I have no doubt, from what he said to me the other day, that he will not soon return to Egypt, but will remain in South Africa until the whole of the trouble there is settled and the railways are reorganised. I will now ask gentlemen present to offer any remarks they may wish to make.

Sir GUILFORD MOLESWORTH: We are all very much indebted to Major Macauley for his description of this most valuable railway, which I think is an historical one in the annals of engineering. But as it often happens in pushing a railway like this for military or political purposes, it is sometimes compared with impatience by the public with other railways which do not make so great a progress; and it is often very unfair to the engineer in charge of a railway to find his work criticised by the public, who do not realise the difficulties that have to be encountered.

It has fallen to my lot to be officially connected with a large number of railways that have been pushed forward for military purposes, and notably with the desert line across Beluchistan, the line up the Bolan Pass, the Rawal Pindi line to the foot of the Kyber Pass, the Burmese and the Uganda Railways. Two of these form a remarkable contrast; one is the desert line across Beluchistan, and the other is the Uganda Railway. On the Beluchistan Railway we completed ninety-five miles in a little more than two months, and the last twenty miles were completed at an average rate of three and a quarter miles per day. On the Uganda Railway we took a year to complete one hundred miles, and I think our maximum—perhaps Mr. Welby will correct me if I am wrong—was about a mile and a quarter per day.

A comparison between these two lines will probably give some idea of the reasons for the difference of the rate of progress. In Beluchistan the gradients were about 1 in 2,000, on a dry, barren, treeless, houseless plain, rising all the way; on the Uganda the gradients were 1 in 50 and 1 in 66 on the permanent line, and 1 in 30 on the temporary diversions. In Beluchistan the desert was absolutely smooth and plain, while in Uganda it was mountainous, broken and rolling in parts, with long stretches of flat ground. In Beluchistan there were practically no curves, and in Uganda the sharpest curves were 573 feet radius on permanent, and 400 on temporary lines; and there were 46 miles of curves in 200 miles. On the Beluchistan Railway the effective hauling power of the locomotives was about eleven times that of the locomotives on the Uganda Railway; that is, taking into account the gradients, curves, and loads hauled. On the Beluchistan neither clearing nor grubbing were required; on the Uganda, in the first 400 miles there were 13½ per cent. of open country, 19 per cent. of open country with scrub and jungle, 5½ per cent. of open country with patches of forests, 11 per cent. of open country with thin jungle, 5½ per cent. of dense forest, and 45½ per cent. of dense thorny jungle. In cases of light earthwork the grubbing up involved more labour than the earthwork itself. In Beluchistan it had been intended to make a bank of at least one foot high across the desert, but the urgency of the case forbade any earthwork; on the Uganda Railway the work was very heavy in parts, with rock cuttings and high embankments, but there were also long stretches of easy work. There were no bridges on the Beluchistan Railway, but on the Uganda Railway there were 43 spans, from 10 to 60 feet, in 200 miles, excluding culverts and spans of less than 10 feet, and also excluding the large Macupa trestle bridge which I referred to in my Paper yesterday. In Beluchistan skilled native labour was plentiful; in Uganda almost all the native labour was imported under plague restrictions, and the workmen were new to the country and its conditions. In Beluchistan the subordinates were well trained and experienced, they could be obtained in abundance and were accustomed to the natives of the country; in Uganda there was great difficulty in obtaining subordinates, and many of them who were obtained from India proved to be inebriates or inefficient. In Beluchistan the engineering staff and officers had for years carried on public works in a neighbouring district with the same labourers; in Uganda the officers were new to each other and to the country, and many of them were new to the language and character of the Indian coolie. In Beluchistan, all India was available for the supply of transport

animals, and 600 military carts and drivers were placed at the disposal of the platelaying staff; in Uganda there were no transport animals, and nearly all those imported—63 camels, 128 mules, 579 bullocks, and 774 donkeys—died from the effects of the tsetse-fly. In Beluchistan any unforeseen want could be supplied at once by railway if telegraphed for, and written explanations reached headquarters in a few days; in Uganda any unforeseen want, if telegraphed for, could not be supplied until great delay had occurred, and explanations, owing to the infrequency of the mails and the length of voyage, required usually more than a month to reach destination. In Beluchistan the food supply was unlimited, while in Uganda all food for coolies had to be imported, and it was necessary to establish corn-mills and to work them night and day to supply the coolies. In Beluchistan materials of all kinds could be brought by the railway from any part of India, while in Uganda nearly everything had to be imported. In Beluchistan there was excellent water both for drinking and for the locomotives at the base; in Uganda, water, where obtainable, was generally bad, both for drinking and for the locomotives, and at Kilindini terminus it was necessary to erect condensing apparatus. In Beluchistan the health of the men was perfect, and the weather delightful; in Uganda, although the mortality was not great, there was a terrible amount of sickness, chiefly fever. In Beluchistan there were long-established and well-organised workshops, available with every appliance for repairs; in Uganda there were only temporary workshops and a very limited supply of machine tools and appliances. During the construction of the Beluchistan railway there was no rain, but after completion the line was breached in many places when the rains came on; in Uganda during construction there were heavy rains at times which washed out the new earthwork and temporary bridges. In Beluchistan no temporary diversions were necessary; in Uganda 21 miles of temporary diversions were required in 200 miles, involving 98 temporary bridges. In Beluchistan no inconvenience was suffered from wild beasts, while in Uganda 28 coolies were eaten by man-eating lions, and gangs had to be sent away to safe places by train every evening and brought back in the morning. In Beluchistan there was no difficulty in obtaining any quantity of locomotives from our supply in India; while in Uganda, owing to the engineering strike in England, it was impossible for us to obtain sufficient locomotives. Some were purchased from India, but they were second-hand engines, twenty years old, and of insufficient power; and the supply was never equal to the necessities of the case. In Beluchistan all the locomotives and rolling stock were delivered at the base in perfect order, while the Uganda rolling stock had to be erected at the base and was subject to the heating of bearings and axle boxes usual in new stock. In Beluchistan there was no difficulty in moving the trollies in laying the permanent way rapidly, while in Uganda gradients of 1 in 30 and curves of 400 feet radius, on temporary diversions, rendered the movement of trollies very difficult. It will be seen, therefore, that any comparison between the relative progress of these two lines would be absurd.

Sir DOUGLAS FOX: We are very much indebted to the author of this Paper, who, under the circumstances, has been kind enough to respond to our request. I think it is a very valuable record of a line constructed under

very special circumstances. I quite agree with the last speaker that it is very unfair, without having a full knowledge of all the circumstances of every case, to make invidious comparisons either as to speed or cost. At the same time, I think it is wise to utter a word of caution, especially to our younger members, that a line of this kind should not be considered as a system to be adopted, except under emergency. It is absolutely necessary, no doubt, owing to the special urgent circumstances in which this railway was built, that different types of rail and some seven or eight types of locomotives should be adopted; but it is desirable to point out that this must lead, in the future, either to the withdrawal of a large number of the locomotives and the relaying of the permanent way, or else must entail very serious difficulty and cost of maintenance. Therefore that system should certainly not be introduced, except where military urgency calls for it, and then we have only to praise the way in which that particular difficulty has been overcome. We have heard a great deal about the Atbara bridge, and we are told that it consisted of seven spans of 150 feet each. Now, I can never understand how there can be any difficulty in obtaining a bridge of such an ordinary type. If special designs are made which do not utilise the ordinary standards, of course undue time is necessary for their completion. As I understand, those who did supply this bridge were allowed to do so upon their own patterns; I am quite certain that our makers, either in Scotland or England, would readily have complied with the requirements as regards speed if the ordinary type of bridge had been adopted.

There is one point in this Paper which gives me infinite satisfaction; this line must form in part the foundation in the future of the Cape to Cairo Railway, on which some of us are actively at work. We have arrived 1,500 miles from Cape Town towards the north, and whoever had to settle the question of gauge here is greatly to be congratulated upon the adoption of the 3 feet 6 inch gauge. No doubt that gauge will be extended down to the coast of Egypt in the future, and it will form, I should think, the standard gauge of that part of Africa. I think that we, as engineers, must always endeavour, as far as possible, to deprecate break of gauge and must encourage a uniform system. Therefore it is satisfactory that the 3 feet 6 inch gauge has been adopted, even on this temporary railway, which is the foundation, to some extent, of the future railways.

Sir Guilford Molesworth has given us a very interesting contrast between two railways, and I should like to say a few words as to what has been done in Bechuanaland and Rhodesia. With reference to the engines which have been spoken of as the Bechuanaland type, our company were able to allow them to be delivered to this railway in order to meet the convenience of the Government. We were not quite in such a hurry for our locomotives, and they were consequently transferred from our contract. The Rhodesian system of railways now amounts to nearly 2,000 miles of 3 feet 6 inch gauge, with 60lb. rails, steel sleepers, masonry piers, steel tops to bridges, ballast in all soft grounds, complete arrangements for water supply, passing places every fifteen miles, and a supply of rolling stock such as enables us to carry a considerable traffic in spite of the difficulties of the war. Our average cost up to date is just upon £4,000 per mile; considering the length of the

system this is not a bad result. The only thing further I should like to have added is what the cost of this railway has been.

Sir GUILFORD MOLESWORTH: I may say that I am not responsible for the metre gauge of the Uganda Railway. I recommended to the Imperial British East Africa Company preferably the 3 feet 6 inch gauge.

The CHAIRMAN: The Author is at Khartoum, and cannot therefore reply to the discussion; but I think it requires very little reply. No doubt he would agree with Sir Douglas Fox that this line, which was constructed under emergency, is not to be taken as a model as far as regards locomotives, as the Author says they had to take what they could. I may also say that brother engineer officers of his in South Africa have also taken what they could; and it will be interesting to note that in some cases they have taken the driving wheels off the locomotives, bored them out, refitted them to the field guns, and they have answered perfectly well. That, I think, is a good thing done by them out there. The Atbara bridge, evidently, caught our makers napping; they could do it perfectly well, as Sir Douglas Fox said. In the case of one bridge which was blown up by the Boers, I was asked by the Cape Government to get it replaced as quickly as possible, and I got it done in this country within three weeks.

I have nothing now to do but to ask you to join me in a very cordial vote of thanks to Major Macauley, which I shall have very great pleasure in communicating to him. (*Carried by acclamation.*)

Mr. B. HALL BLYTH, M.A., Member of Council Inst.C.E., in the Chair.

[PAPER.]

AUSTRALIAN RAILWAYS.

By Professor W. C. KERNOT, M.A., M.C.E., M.Inst.C.E.

INTRODUCTION.

To adequately discuss the railways of Australia would require a treatise of several hundred pages. All that will be attempted in the present Paper is a brief outline, such as might suitably form the introductory chapter of such a treatise, leaving the detailed consideration of the various branches of the subject to subsequent portions of the book.

The island or continent of Australia is about 2,500 miles long from east to west, and 2,000 broad from north to south. Its area is about 3,000,000 square miles, or approximately that of the United States of America; and its climate in the southern and most populous parts is that of southern Europe, and in the northern parts that of India. It produces wool, wheat, horses, cattle, sheep, leather, dairy produce, fruit, sugar, coal, gold, copper, tin, and other metals. It has a population of 3,800,000, which is steadily increasing. Its largest cities are Sydney and Melbourne, containing almost exactly half a million people each. It is divided into five separate States, originally independent colonies, but recently federated together, with the small adjoining island of Tasmania, under one Government with the title "Commonwealth of Australia."

Its physical features are peculiar. Around the greater part of its circumference, at a comparatively small distance inland, a fairly well defined range of mountains occurs. This is specially marked on the eastern coast and the eastern portion of the southern coast, where it presents one peak over 7,000 feet and several peaks over 6,000 feet high. The passes whereby railways and roads cross the range are rarely less than 1,000 feet high, and in one case as much as 6,000 feet. Outside the range the country is fertile, varied in character, often hilly or even mountainous, and fairly well watered by torrential rivers, which are sometimes navigable for a short distance from their mouths. Inside the range the country is generally more or less arid, the streams are long and tortuous, precariously navigable for shallow-draught steamers, and, except in the south-eastern part, never reach the ocean at all, but lose themselves in swamps and shallow lakes. In the eastern half of the continent this inland basin is fairly good for pastoral purposes, and in some parts for farming, though its value is greatly reduced by the periodical droughts to which it is subject. In the western half it is a practically waterless desert, but which in some parts carries a considerable population owing to the presence of rich deposits of gold.

The inner slope of the coast range is usually flatter than the outer, and in many parts the summit of the range, instead of being a well-marked ridge,

spreads out into a broad table-land 2,000, 3,000, or even 4,000 feet above the sea. These table-lands have a comparatively cool climate, a good rainfall, and are often fertile and well populated, needing railways and roads of considerable length.

Gauge of Lines.

Railway construction commenced at Sydney in 1850, and at Melbourne about two years later, in the hands of private companies; but these had to be assisted by Government in some cases, being unable to complete the work they had undertaken. A line from Sydney to Liverpool, from Newcastle (a port about seventy miles north of Sydney) to Maitland, from Melbourne to Geelong, and several short suburban lines at Melbourne were thus constructed.

Great discussions took place at this time as to the gauge to be adopted. Victoria, South Australia, Tasmania, and the colony of New Zealand after careful enquiry adopted the Irish gauge of 5 feet 3 inches; while New South Wales, after having at first adhered to that gauge, and at a time when the other colonies had already placed large orders for rolling stock, changed its decision and adopted the English gauge of 4 feet 8½ inches. In 1857, the New South Wales railways were taken over by the Government, who appointed Mr. John Whitton, M.Inst.C.E., as Engineer-in-Chief. This gentleman assured the writer that he did his best to induce the Government to alter the gauge to that of the adjoining colonies, but without avail, the result being that that State now has 2,811 miles of railways on a gauge that exists nowhere else in Australia, and the evils of break of gauge exist wherever the lines cross the frontier.

After this Queensland, a large and very thinly populated colony, decided to commence railway construction; and the distances being great, the coast range rugged, and the funds available limited, it was decided to abandon the broader gauges and adopt the narrow gauge of 3 feet 6 inches. Western Australia did the same, and New Zealand and Tasmania, after having made and worked a few miles of 5 feet 3 inch gauge for some years, adopted 3 feet 6 inches for all extensions, and changed the short lengths of the wider gauge into the narrow.

South Australia, which had made a much greater length of the Irish gauge than Tasmania and New Zealand, retained it for its principal lines, and the one communicating with Victoria; but adopted 3 feet 6 inches for a secondary system to serve the more remote and less populous parts. Thus Victoria alone remained faithful to the original choice. But even in Victoria and New South Wales strong pressure was brought to bear, about the year 1870, to induce the Governments to have all further extensions on the narrower gauge. This, however, was successfully resisted by the Engineers-in-Chief of the two colonies, T. Higinbotham, M.Inst.C.E., and John Whitton, M.Inst.C.E. In Victoria, so strong was the pressure that tenders were actually invited for the two lines, one in easy and the other in rather difficult country, both on 5 feet 3 inch and 3 feet 6 inch gauge, the result being that the narrower gauge showed a saving of only £150 per mile in the former and £181 in the latter case. After this all railway-making in Victoria continued on the 5 feet 3 inch gauge until the last two years, during which two short lines of 2 feet 6 inches have been built under very special conditions.

The state of the gauge question in Australia at present is shown by the subjoined table :—

	5 ft. 3 ins.	4 ft. 8½ ins.	3 ft. 6 ins.	2 ft. 6 ins.
	Miles.	Miles.	Miles.	Miles.
Victoria	3,218	...	...	48
New South Wales .	...	2,811		
South Australia . .	507	...	1,374	
Queensland . . .	...	...	2,801	
Western Australia .	...	...	1,355	
Tasmania	...	...	440	
Totals . .	3,725	2,811	5,970	48
Grand total . . . 12,554 miles.				

The above are State or Government railways. In addition there are in all nearly 1,000 miles of private railways, mostly 3 feet 6 inch gauge, used mainly for mining and timber getting. Of these over 500 miles are in Western Australia.

What the future of this most regrettable state of things will be it is hard to say. At present great inconvenience and loss arise from it, and as lines extend and cross State borders at fresh points the trouble will increase indefinitely.

Gradients.

Owing to the peculiar configuration of the country, grades of exceptional length and steepness are of frequent occurrence. The record railway for severe grades is that extending from Sydney in a generally north-western direction to Bourke, 500 miles in the interior. For the first 35 miles this line is of very ordinary character, never rising much over 100 feet above the sea. Then it crosses the Nepean River, a main watercourse of great importance, and at once ascends a spur of the main coast range, called locally the Blue Mountains. Commencing with nearly two miles of 1 in 30, followed by many miles of alternately 1 in 33 and 1 in 66, after an ascent of 30 miles in length the line reaches Katoomba, 3,360 feet above sea-level. For the next 30 miles the line varies between 3,300 and 3,700 feet, when it reaches the Great Zigzag, where, by the aid of two reversing stations and a long length of 1 in 42, a descent is made into a valley which still is on the coast side of the main range. Thence a moderate ascent reaches the true summit of the range and the descent of the inland slope commences, but does not continue far before another ascent is needed to reach one of the before-mentioned fertile *plateaux* at a height of 3,131 feet above the sea. After this it falls rapidly over undulating country until at about 1,000 feet above the sea, and over 200 miles from the point when it first ascended the range, it leaves the mountains fairly behind and extends 250 miles across plains, slowly falling to the west.

The principal line in Victoria, extending north from Melbourne to the

River Murray, rises 1,880 feet in 42 miles, having continuous grades of 1 in 50 for miles together, interspersed with flatter grades ; it then crosses the coast range, and falls gently for 20 miles. It then rises again to the Elphinstone Tunnel, and falls steeply to the town of Castlemaine. After this is a further rise to the Big Hill Tunnel, followed by a steady fall to Bendigo, 758 feet above the sea, 100 miles from Melbourne, and Echuca, 320 feet above the sea, and 156 miles from Melbourne. One branch of this line reaches an altitude of 2,452 feet at 60 miles from Melbourne, where the rails are only 18 feet above the sea.

The capitals of the four principal Australian States are connected by a railway 1,783 miles long, over which the inter-State express trains travel.

Starting from Adelaide, 150 feet above the sea, the line almost immediately commences to ascend the coast range, 10-chain curves and 1 in 45 grades abounding, and the line being so circuitous that two stations, 8½ miles apart by railway, are only a little over one mile apart by road. Numerous short tunnels are traversed and also two fine American trestle viaducts, one more than 100 feet high, and situated on a 10-chain curve. At 20 miles a height of 1,615 feet is reached. Then commences a steady descent of 40 miles to Murray Bridge, after which the line continues of a fairly level character to Ararat, 351 miles, when the coast range is again crossed at about 1,000 feet above the sea. The line then crosses spurs extending south from that range, involving many steep ascents and descents, and passing the important mining city of Ballarat. In crossing one of these spurs it reaches a summit level of 1,940 feet, and a few miles further on descends 987 feet in 11 miles, traversing on the way a curve slightly more than a semicircle, of 35 chains radius ; thence to Melbourne, 482 miles, the line is moderately level.

Leaving Melbourne the line rises slightly more than 1,100 feet in 33 miles, crosses the coast range, and then descends by 1 in 50 grades and numerous curves to about 500 feet. It then continues at about the same average level, but with local undulations, involving rises and falls of about 200 feet, to Albury, when it crosses the border, and the gauge, which has been 5 feet 3 inches for 672 miles, becomes 4 feet 8½ inches. The line slowly rises, the country becomes hilly, grades of 1 in 40 become common, until at 904 miles the coast range is crossed for a fourth time at 2,400 feet above the sea. Thence to Hill Top, 989 miles, the level undulates between 2,350 and 1,960 feet. From Hill Top to Picton, 16 miles, the line falls 1,488 feet, with grades in some cases as steep as 1 in 30. Thence to Sydney it is moderately level.

Leaving Sydney, which is 1,061 miles from Adelaide, the line rises 612 feet in 28 miles and then falls 668 feet in 8 miles. It here crosses the Hawkesbury River by a very fine bridge of American construction, and continues fairly level to Newcastle, 1,163 miles. It then turns inland, follows up the valley of the River Hunter, and crosses the coast range for a fifth time at 2,073 feet above the sea. This is followed by a descent to 1,300 feet, followed by a rise of 1,792 feet in 20 miles. After this follows a series of gentler ascents until at Ben Lomond, 1,461 miles, the summit-level of the whole journey is reached, 4,473 feet above sea-level. At 1,551 miles from Adelaide the Queensland border is crossed at an altitude of 2,876 feet. Here the gauge changes to 3 feet 6 inches, and the line falls

steadily to 1,524 feet in about 100 miles; it then rises to 2,003 feet, at which level it crosses the coast range for the sixth time, and descending 1,215 feet in 17 miles, 749 of which are done in 9 miles, reaches comparatively level country, extending 80 miles to Brisbane, which is only a few feet above sea-level, and 1,783 miles from Adelaide.

The Alpine character of this, the main line connecting the capital cities of southern and eastern Australia, is evidenced by the fact that of the total distance of 1,783 miles, 134 are above 3,000 feet altitude, 409 above 2,000, and nearly 800 above 1,000 feet.

Of late years, both in New South Wales and Victoria, much money has been spent in re-grading the lines, and where the steep grades are comparatively short, great improvements have been effected. But this is possible only where the country undulates, but has but little general rise or fall. The severest grades on the whole system of 1 in 50, 1 in 40, or even 1 in 30, for several miles together, followed by miles of line ascending at but slightly easier grades, are unavoidable.

Curves.

In Victoria the configuration of the country usually admits of curves of fairly large radius. On the principal lines there are long stretches of straight, and the curves, when they do occur, are usually not sharper than 40-chains radius, and the same is the case in considerable portions of South Australia. In crossing the coast range behind Adelaide, however, the rugged nature of the ground compels the employment of 10-chain radius curves on the main Irish gauge railway.

In New South Wales the rugged rocky nature of the coast range led to the employment of 8-chain curves, which in some instances occurred on the 1 in 33 grades and formed a very serious impediment to the traffic. Portions of this system have recently been re-located and re-graded with great advantage, and now 12 chains is the smallest radius.

On the 3 feet 6 inch lines in Queensland, South Australia, West Australia, and Tasmania, curves of 5-chains radius are used freely. In recent extensions and reconstruction of old lines, curves of transition have been adopted with great advantage at the entrance of the sharper curves.

Permanent Way.

Australian railways are nearly always well ballasted with broken basalt, broken freestone of a hard character, or good gravel, though attempts are being made to dispense with ballast on pioneer lines in New South Wales. The sleepers are of eucalyptus timber, very strong and hard, sawn or hewn to rectangular section. On some of the very early lines double-headed iron rails of 80 lbs. to the yard in cast-iron chairs with wood keys were used, but for the last quarter of a century all new lines and all renewals on old lines have been made with flat-bottomed or Vignoles rails of steel, spiked directly on to the sleepers. The latest standard rails in Victoria are :—

Melbourne suburban system	100 lbs. per yard
Main country lines	80 „ „
Secondary lines	60 „ „

PHOTOGRAPH OF A LECTURE MODEL USED AT THE UNIVERSITY TO ILLUSTRATE THE STANDARD 15-FOOT SPAN TIMBER BRIDGE, ADOPTED ON THE VICTORIAN RAILWAYS.

The most recent fishplates are of channel section 2 feet 6 inches long with six 1-inch bolts. As a rule the Australian lines are solid and well kept, and accidents from derailment are comparatively rare.

In populous parts the lines are strongly fenced, and road crossings are provided with gates; but in country districts gates are usually dispensed with, and cattle guards employed to prevent animals straying along the line. In many parts the locomotives are provided with cow-catchers, as in America.

Structures.

For culverts and smaller bridges, colonial eucalyptus timber is largely employed in Victoria, New South Wales, Queensland, and Tasmania. Many miles in length of the standard 15-foot span timber bridge, employed on the Victorian railways, have been used on important lines carrying fast and heavy traffic. At Yarraglen, near Melbourne, there is a continuous length of 113 chains of this type. The cost of such a structure, averaging 15 feet in height from the ground level to the rails, with piles well driven, is usually about 30*s*. per foot run. In districts where timber is not easily accessible, stone, brick, iron or steel structures are used, and even where timber is cheap its use is confined to spans not usually exceeding 50 or 60 feet. Of large bridges and viaducts the following may be noted:—

New South Wales possesses the Hawkesbury Bridge, seven spans of 416 feet, double line, steel girders, erected by the Union Bridge Company, of New York, at a cost of about £350,000. Piers consist of steel caissons filled with concrete, and extend 160 feet below water-level. The Penrith Bridge, three spans of 198 feet each, double line, iron box girders, stone piers. Menangle Bridge, ditto, three spans of 159 feet.

At Dubbo, Wellington, Aberdeen, George's River, Wagga, Tamworth and other places are single line lattice girder bridges on cast-iron cylinder piers, having respectively from one to six spans of 159 feet each. At Albury is a double line lattice girder bridge, two spans of 159 feet each on cast-iron cylinders. At Knapsack Gully, on the 1 in 30 grade up the Blue Mountains, is a very fine stone viaduct, single line, 125 feet high and about 300 feet long. There are also numerous plate girders of 30 to 60 feet span; also stone, brick, and, in two cases, Monier concrete arches as overbridges.

Victoria possesses the Moorabool Viaduct, ten spans of 130 feet each, basalt piers 110 feet high, Warren continuous girders, originally double line, now reduced to single line, cost £200,000. The Taradale Viaduct, five spans of 130 feet each, basalt piers 100 feet high, box girders, double line. The Melton Viaduct, trestle construction, 125 feet high, 1,200 feet long, spans 60 feet and 30 feet alternately, discontinuous iron lattice girders, built for double line, but at present carrying single line only, cost about £120,000. The Echuca Bridge, cast-iron cylinders carrying wrought-iron plate girders—total length 1,452 feet, largest span 112 feet, smallest 45 feet, greatest height 60 feet, built for double line, but at present carrying a single line only. The Saltwater River Bridge, basalt abutments, wrought-iron box girders, 200 feet span, double line.

There are also many others of less magnitude, including a very interesting

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cantilever bridge at Toolamba, a hog-back steel girder double line bridge of 140 feet span at Cremorne, near Melbourne, and many plate and lattice girder bridges of from 60 to 100 feet span. The largest stone viaduct is at Malmsbury; it is 75 feet high, has five arches of 60 feet clear span, is built of local basalt, and carries a double line of way.

Queensland possesses very many fine iron and steel bridges, the rivers there, owing to tropical conditions, being larger and more numerous than in the southern parts. The most notable is the Albert Bridge over the Brisbane River, double line, steel hog-back girders, two spans of 340 feet each.

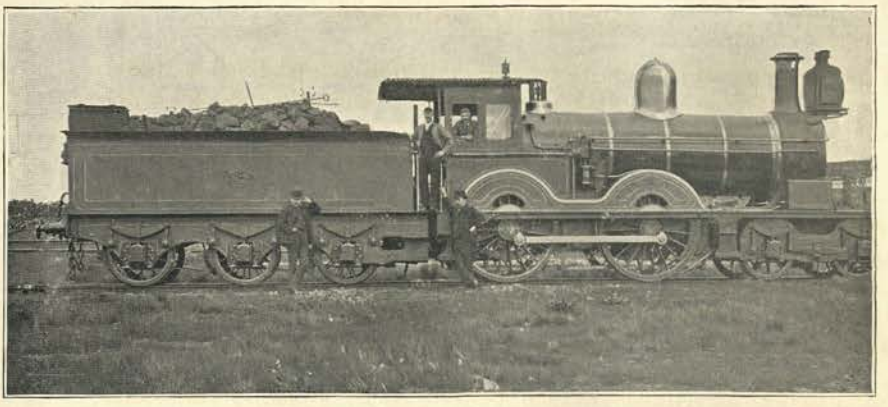
Tunnels are not very numerous in Australia, nor, when they do occur, are they usually very long. New South Wales has two tunnels of about a mile in length each, and a fair number of shorter ones. Victoria has only two double line tunnels of about a quarter of a mile each, a single line tunnel of about the same length, and two of a few chains only. It has also two short cut-and-cover double line tunnels on a suburban line not yet completed. South Australia has several short single line tunnels on the ascent of the coast range near Adelaide. Queensland, Tasmania, and Western Australia have a few tunnels each, but on the whole Australia is not a country requiring much tunnelling. Australian tunnels are always substantially lined with masonry or brickwork, and have required but little maintenance, although some of them are about forty years old.

Station buildings are usually of English type, and high platforms are employed, enabling passengers to enter and leave the carriages with facility. At Melbourne and Sydney the permanent termini have yet to be built, cheap temporary accommodation having been employed hitherto. No doubt it was a wise policy to delay the construction of costly permanent stations until the traffic was well developed, and its requirements accurately known. Nevertheless, it has the disadvantage of provoking unfavourable comment from visitors who are accustomed to the palatial erections of older countries. Both the above capitals are, however, now moving in the direction of providing permanent stations which shall be architecturally a credit to the city. The goods stations are, as a rule, fairly well equipped throughout Australia; ample platform accommodation, closed buildings for goods likely to be damaged by weather, crane power, etc., being provided. The signalling appliances, on the English system, are usually fairly perfect, and interlocking points and signals are used at important stations and junctions.

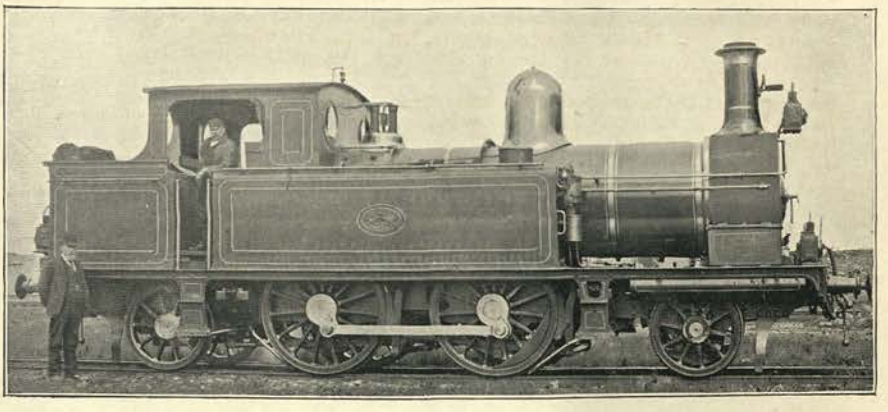
Locomotives.

Owing to the severity of the grades and the nature of the traffic, the type of locomotive most used differs somewhat from those generally seen in England. Smaller driving wheels, the universal employment of coupling rods, and the total absence of the single-driver engine at once attract notice. Types of engines which in the mother country are always used for goods traffic are constantly seen on passenger trains in Australia. In Victoria, the long since defunct Geelong and Melbourne Railway Company imported in the early fifties several single-driver engines, but these did not survive long, being speedily either altered into four-coupled with reduced wheels or utilised as stationary engines at the railway workshops. In the course of years many

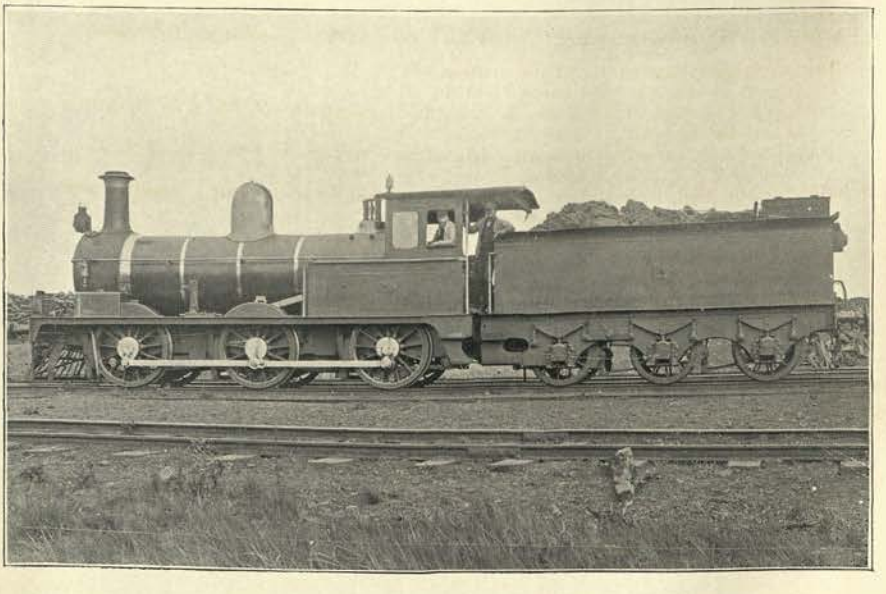
TYPES OF LOCOMOTIVES ON VICTORIAN RAILWAYS.



PASSENGER TRAIN LOCOMOTIVE. CLASS A.



LOCOMOTIVE FOR SUBURBAN TRAFFIC. CLASS E.



LOCOMOTIVE. CLASS Y.

types of engine were obtained, the majority from England, but a few from America. Most of them had inside cylinders, but a considerable minority had outside cylinders. About fifteen years ago the number of different types became intolerably great, and it was decided to establish certain standards and adhere to them in future; and this has since been done, though not without occasional deviations. For the passenger trains on the main lines a type called A is employed. It is a four-coupled leading-bogie tender engine, having a general resemblance to those of the Midland, Great Eastern, Great Central, or Caledonian Railways. Its dimensions are as follows:—

PASSENGER TRAIN LOCOMOTIVE. CLASS A. (Victorian Railways):

Firebox surface, 95 sq. ft. Tube surface, 1,056 sq. ft.
Grate area, 21 sq. ft. Cylinders, 18 in. by 26 in.
Driving and coupled wheels, 6 ft. Bogie and tender wheels, 3 ft. 6 in.
Buffer and wheel spacing, measuring from front backwards, 3 ft. 9 in., 5 ft. 8 in., 7 ft. 2 in., 8 ft. 3 in., 8 ft. 8 in., 5 ft. 6 in., 5 ft. 6 in., 5 ft. 3 in.
Bogie axle load, 7 tons 5 cwt. Driving axle load, 14 tons 15 cwt. Coupled axle load, 13 tons 16 cwt.
Total weight of engine in steam, 43 tons 1 cwt.
Weight of tender, with 2,200 gallons of water and 3 tons 10 cwt. coal, 29 tons 19 cwt.
Tractive force, 11,700 lbs.
Height of funnel from rail, 13 ft. 6 in.
Steam pressure, 140 lbs. per sq. in.

Recent engines of this type work at 175 lbs. pressure and have piston valves. A second standard type is designated D. It is similar to A but smaller; its boiler cylinders and driving wheels correspond in size with type E described below.

The type E is used on the suburban railway system of Melbourne, and occasionally elsewhere. It runs either end forward, and has radiating axle boxes to its trailing wheels; seventy-five of these are in regular work.

Its dimensions are as follows:—

LOCOMOTIVE FOR SUBURBAN TRAFFIC. CLASS E. (Victorian Railways):

Firebox surface, 83·5 sq. ft. Tube surface, 971 sq. ft.
Grate area, 17·8 sq. ft. Cylinders, 17 in. by 26 in.
Driving and coupled wheels, 5 ft. Leading and trailing wheels, 3 ft. 6 in. Trailing has radiating boxes.
Buffer and wheel spacing, measuring from front backwards, 6 ft. 8 in., 7 ft. 9 in., 6 ft. 8 in., 6 ft. 5 in., 6 ft. 2 in.
Driving axle load, 15 tons 3 cwt. Coupled axle load, 14 tons 3 cwt. Leading and trailing axle load, 10 tons 6 cwt.
Total weight of engine in steam, with 1,600 gallons of water and 2 tons 10 cwt. coal, 49 tons 18 cwt.
Tractive force, 12,500 lbs.
Steam pressure, 140 lbs. per sq. in.

A fourth standard is known as Y. Its furnace, boiler, cylinders, and tender correspond to those of A, but it has 4 feet 6 inch wheels and no bogie. Its dimensions are as follows:—

LOCOMOTIVE. CLASS Y. (Victorian Railways):

Total weight in steam, 40 tons 9 cwt. (engine only).
Maximum axle load, 14 tons 7 cwt.
Tractive force, 15,600 lbs.

The last standard form is that known as R. It is similar to Y but smaller; its total weight in steam is 38 tons, and its maximum axle load is 13 tons.

These standard engines, together with many of their now obsolete predecessors, were constructed locally, being copied, with occasional modifications, from imported types. The A and E types were successful engines from the first, but the Y and R and, to a lesser extent, the D engines were not, being complained of as slow, uncomfortable, and rough on the road. The insertion of suitable balance weights in the wheels has, however, remedied these defects, and the performance of all the standard engines is now regarded as satisfactory.

All these engines are fitted with the Westinghouse brake, and all except E with cow-catchers, which are found a great security on unfenced lines, and at road crossings, which, in many cases, are not provided with gates or gate-keepers.

The climate being hot and dry in summer, considerable complaints have arisen as to the locomotives causing grass fires. To meet these, wire gratings are placed inside the smoke-box, and a wide strip of land being taken for the railway, the grass is burnt off in early summer so as to provide an area on which sparks may fall harmlessly.

In New South Wales the excessively steep grades, combined with specially sharp curves, such curves constituting in many parts the greater part of the total length of the line, rendered the choice of a suitable locomotive a matter of much difficulty. At the outset, six-coupled inside cylinder engines were employed, but these, though good for pulling, ground their flanges away with great rapidity on the curves. They were followed by outside cylinder engines, with four-coupled driving wheels of 5 feet 6 inches diameter, and 18-inch by 24-inch cylinders, with a leading bogie and an ordinary six-wheeled tender for passengers; and a six-coupled engine, having 4-feet drivers, and a two-wheeled pony truck to ease it round the curves for goods; the type being that known as Mogul in America, the details of the engine, however, being British. Of late years still larger and more powerful engines have been introduced with the most satisfactory results both for passenger and goods traffic.

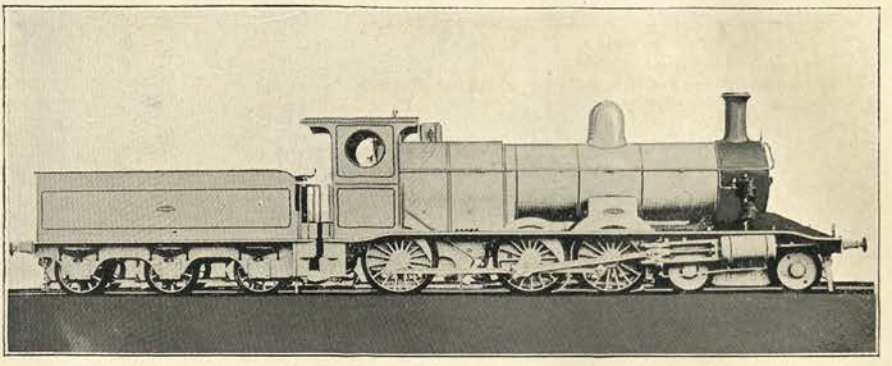
The heavy express outside cylinder engine (Class P) has a considerable resemblance to the great six-coupled express engines of the North-Eastern Railway, but the driving wheels are smaller. This class of engine was built by Beyer & Peacock, of Manchester. It has indicated 1,080 H.P. while pulling a net load of 165 tons up a 1 in 42 grade at 20 miles per hour, and has taken the same load up 1 in 30 at 18 miles per hour.

For goods traffic an even larger engine has been introduced, capable of drawing a net load of 354 tons up 1 in 43 at 13 miles per hour, and 697 tons up 1 in 100 at 15 miles per hour. For suburban traffic a type known as M is used, rather larger than the Victorian E, and fitted with a leading bogie, which is doubtless justified by the more sinuous character of the lines.

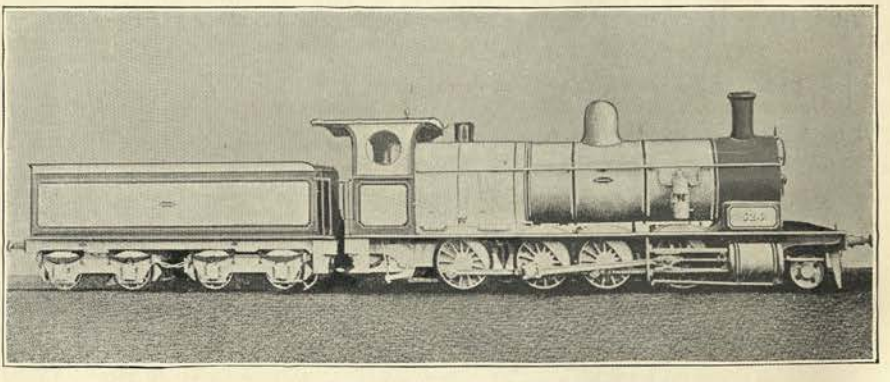
As in Victoria, the engines are all fitted with the latest type of Westinghouse brake.

Particulars of these engines are given on the following page.

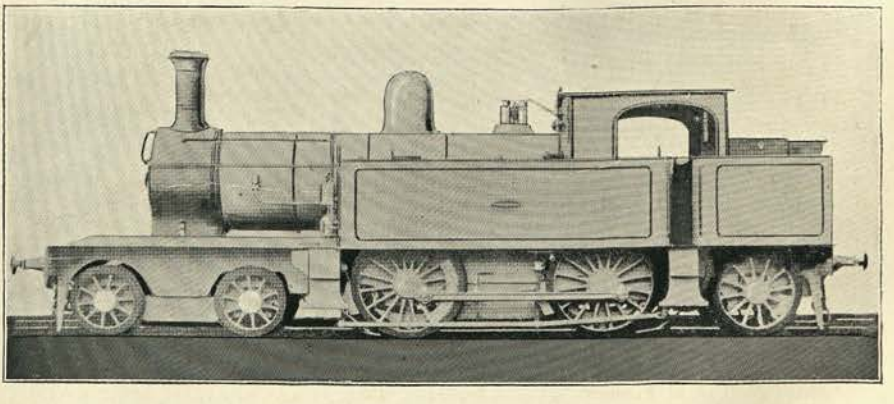
TYPES OF LOCOMOTIVES ON NEW SOUTH WALES RAILWAYS.



EXPRESS AND MAIL TRAIN ENGINE. CLASS P.



GOODS ENGINE. CLASS T.



SUBURBAN TANK ENGINE. CLASS M.

EXPRESS AND MAIL TRAIN ENGINE. CLASS P. (New South Wales Railways.)

PRINCIPAL DETAILS.		ft.	in.
Diameter of bogie wheels		3	3
Diameter of coupled wheels		5	0
Cylinders, 20 inches diameter by 26 inches stroke.			
Heating surface: Tubes	1,786 square feet.		
Firebox	130 „		
Total	1,916 „		
Total grate area	27 „		
Boiler pressure, 160 lbs. per square inch.			

Weight in working order:—	t.	cwt.	q.
Bogie (4 wheels)	14	13	2
Leading wheels (coupled)	14	10	3
Driving „ „	14	13	0
Trailing „ „	12	13	2
Total	56	10	3
Tender	31	16	1
Total engine and tender	88	7	0

Water capacity, 3,030 gallons.
Coal „ 4½ tons.

GOODS ENGINE. CLASS T. (New South Wales Railways.)

PRINCIPAL DETAILS.		ft.	in.
Diameter of bogie wheels		2	9½
Diameter of coupled wheels		4	3
Cylinders, 21 inches diameter by 26 inches stroke.			
Heating surface: Tubes	2,032 square feet.		
Firebox	166 „		
Total	2,198 „		
Total grate area	29¾ „		
Boiler pressure, 160 lbs. per square inch.			

Weight in working order:—	t.	cwt.	q.
Bogie (2 wheels)	6	6	0
Leading wheels (coupled)	14	2	0
Intermediate wheels (coupled)	15	10	0
Driving „ „	15	9	0
Trailing „ „	14	8	0
Total	65	15	0
Tender	41	10	0
Total engine and tender	107	5	0

Water capacity, 3,650 gallons.
Coal „ 6 tons.

SUBURBAN TANK ENGINE. CLASS M. (New South Wales Railways.)

PRINCIPAL DETAILS.		ft.	in.
Diameter of bogie wheels		3	3
Diameter of coupled wheels		5	1
Diameter of trailing wheels		4	0½
Cylinders, 17 inches diameter by 26 inches stroke.			
Boiler pressure, 160 lbs. per square inch.			
Grate area, 18·75 square feet.			

Weight in working order:—	t.	cwt.	q.
Bogie (4 wheels)	15	18	3
Driving wheels (coupled)	14	8	0
Trailing „ „	14	6	0
Radial trailing axle	11	16	2
Total	56	9	1

Water capacity, 1,200 gallons.
Coal „ 2 tons 5 cwt.

Heating surface:		
Tubes	1,108 square feet.	
Firebox	127 „	
Total	1,235 „	

In South Australia, locomotives similar to those of Victoria are usual, but for passenger traffic over the steep grades of the coast range a smaller engine, similar to the New South Wales type P, is used. On the 3 feet 6 inch gauge of Queensland, Tasmania, and Western Australia, outside cylinder engines, with leading bogies or pony trucks, having four, six, or eight wheels coupled, are usual.

The American locomotive is not unknown in Australia, and is regarded as a good engine for sharp curves. The preference usually, however, is for English engines, or locally made engines of English type, which are generally regarded as more economical of fuel and requiring less maintenance.

On one private line in Tasmania the Abt rack is used on grades of 1 in 16 with a fair amount of success. The gauge is 3 feet 6 inches.

Passenger Carriages.

Throughout Australia the European type of passenger carriage has been usually preferred, the American car with end doors and central passage being rarely seen except as a sleeping car or as the ordinary stock of the suburban railways at Sydney.

The older stock, now very generally relegated to branch lines, consists of small four or six wheeled vehicles with separate compartments and side doors; the newer of long carriages, with four or six wheel bogies and steel underframes, having separate compartments and a corridor down one side. In New South Wales the corridor cars are usually entered from the ends only, but in Victoria side doors are provided. In both colonies, vestibules enabling passengers to pass from one carriage to another without exposure to the weather are used. These carriages are very complete and well appointed, and are lit with Pintsch gas; the New South Wales ones are specially elegant in their decoration. In the other colonies, and on the narrow gauge, the carriages are of the usual English type, without corridors, but frequently provided with lavatory accommodation.

In Tasmania, the older passenger stock has end doors and central buffers, the new compartments with side doors and side or double buffers.

Appended are particulars of one of these cars:—

FIRST-CLASS VESTIBULE CORRIDOR CAR. (New South Wales Railways.)

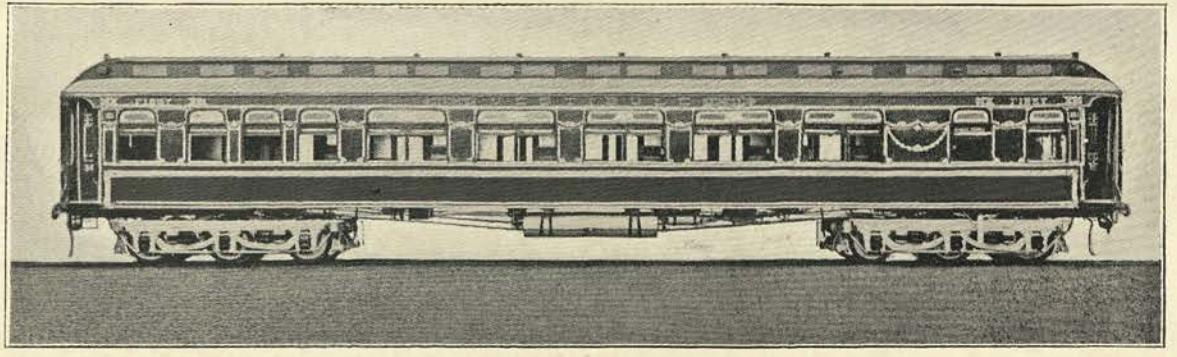
	ft.	in.
Length of body over panels	61	0
Length over buffers	67	11
Width over panels	9	4¼
Height of body inside, from floor to ceiling, at centre	9	0⅝
Capacity	45 persons.	
Tare	36 tons 10 cwt.	

The interior is divided into seven passenger compartments, including a ladies' saloon at one end and a smokers' compartment at the other. Seating accommodation is provided for nine in ladies' saloon, twelve in smokers', and six in each of the intermediate compartments. Requisite lavatory accommodation and vestibules are provided at the ends. Through communication is made from one car to another.

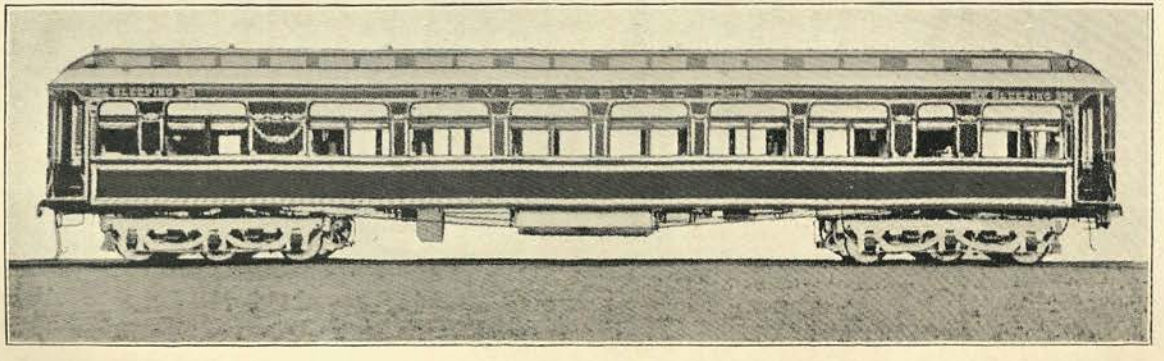
Sleeping Cars.

The great length of the main lines in New South Wales, combined with the slow travelling necessitated by the long and steep grades and sharp and numerous curves, rendered it desirable at an early period to introduce sleeping

TYPES OF ROLLING STOCK ON NEW SOUTH WALES RAILWAYS.



FIRST-CLASS VESTIBULE CORRIDOR CAR.



PULLMAN VESTIBULE SLEEPING CAR.

cars, to perform large portions of the journey by night. For this purpose the American Pullman system has been adopted, and highly-finished and luxuriously-appointed cars are run on the principal lines.

Appended are particulars of one of these cars :—

PULLMAN VESTIBULE SLEEPING CAR. (New South Wales Railways.)

	ft.	in.
Length of body over panels	61	0
Length over platforms	67	11
Width over panels	9	4¼
Height from floor to ceiling in centre of lantern roof	9	0¾
Tare	35 tons 10 cwt.	

The interior is divided into a smoking-room, with lavatories, etc., a main sleeping compartment (in which there are twenty-four berths), and a ladies' saloon containing four berths. It accommodates during the night twenty-eight persons in all, and during the day has seating capacity for fifty-eight persons. Requisite lavatory accommodation and vestibules are provided at the ends. Through communication is made from one car to another.

In Victoria, owing to the smaller size of the country, the very central position of the capital, and the easier grades and curves permitting higher speed, the need of sleeping cars did not press until the completion of a continuous line without break of gauge from Melbourne to Adelaide was accomplished. Then the two Governments, working in conjunction, introduced the Mann car, having a corridor down one side, the remaining space being divided into separate compartments, opening by doors on to the corridor. The compartments contain some two and others four berths, running transversely. This system ensures more privacy than the Pullman, a party of two or four being able to secure a compartment entirely to themselves.

In Western Australia, the sleeping cars have no corridor or other means of communication, but are divided into compartments in the usual European way, lavatory accommodation being provided between each compartment and the next. The ordinary seats form the lower berths, and the upper berths when not in use fold back against the partition.

In Queensland, cars of the Pullman type are used, but on a reduced scale to suit the narrow gauge.

Goods Stock.

This is usually of English type and carried on four wheels, though occasionally larger vehicles, carried on two four-wheeled bogies, as in America, are used. Wagons for carrying live sheep and cattle, louvre vans for dairy produce, and refrigerator wagons for frozen meat, form important sections of the stock. Steel under-frames are common in the more modern portion, and the tubular frame is under trial in New South Wales. Goods stock is usually fitted with the quick-acting Westinghouse brake.

Suburban Railways.

The capital cities of the Australian States are provided with well-equipped systems of suburban railways. Those of Melbourne and Sydney are the most extensive, and a description of the former of these may be useful.

There are two central suburban stations, known as Flinders Street and Prince's Bridge, but they are within a few yards of each other, and will

shortly be combined under one roof; they may, therefore, be regarded as practically one station. From this point six lines of railway extend to the east, four to the south-west, and two to the west. On these twelve lines of way more than five hundred trains depart, and the same number arrive every day, not counting any up-country or long-distance trains. A mile or two out the lines diverge, ultimately leading to eleven different suburbs. The busiest line is that to Sandringham, a distance of 11 miles. The fares for the single journey are 11*d.* first class and 8*d.* second class; for the double journey they are 1*s.* 4½*d.* first class and 1*s.* second class respectively; there is no third class on any of these lines. The time taken for the journey, including ten stoppages at intermediate stations, is 44 minutes. Brighton Beach, an important station 9 miles from town on the same line, is reached by some of the trains in 25 minutes, with five intermediate stoppages. The fares to this point for the single journey are 8*d.* first class and 6*d.* second class; for the double journey they are 1*s.* first class and 9*d.* second class respectively. The preceding represent the average fares on these suburban lines, but in one case, where the route is somewhat circuitous, and tramway competition is present, much lower fares are charged. The distance from Melbourne to Regent Street, Preston, is 9¼ miles, and the fares for the single journey are 3*d.* first class and 2*d.* second class; for the double journey they are 4½*d.* first class and 3*d.* second class respectively. Thus it is possible to travel 18½ miles for 3*d.*, in a well-appointed train, travelling at a fair speed.

These suburban trains run with great punctuality, and their efficiency, combined with the extremely low fares, has greatly promoted the growth of suburbs at distances up to 12 or 14 miles, where the business men of the city reside in roomy and comfortable villas with large gardens and pleasant and healthy surroundings. The Sydney system is very similar to that of Melbourne, but less extensive, and Adelaide, Brisbane, Perth, and Hobart also possess suburban systems on a smaller scale.

Administration.

Though in many cases originally projected, and in not a few constructed and worked for a number of years by private companies, the Australian railways are now with but small exceptions the property of the State, and public opinion is strongly in favour of the continuance and extension of this system. Under it the railways of each State form a consistent and harmonious whole, and the expensive duplication of station accommodation, and construction of competing lines between the same centres, with consequent waste of capital, occupation of valuable land, and increased severance, are avoided. The lines are constructed with money raised in the English market at low rates of interest, the security being the best, namely, that of the Government. So long as the net revenue does not fall very far below that required to meet the interest on the loans, there is no complaint, it being recognised that the indirect benefits of the railways in encouraging settlement, promoting commerce, and raising the standard of comfort in country districts are so great and far-reaching as to fully justify a moderate contribution from the general revenue to supply a deficiency in the railway accounts. The lines are thus made and worked in the interest of the whole community and not that of any private individual, company, or ring. But while this is all admitted, it cannot

be denied that the method has its disadvantages and dangers. One of these is the making of unproductive lines for political purposes. This has been done in several cases in the State of Victoria, and at the present time 16 miles of line have actually been dismantled, the rails being removed and used elsewhere; other portions, but not to any great extent, are not worked, while not a few branch and cross-country lines, which it is not considered politic to close, are worked at a loss and constitute a dead-weight on the finances of the system. These mistakes, made in a time of great apparent prosperity, are not likely to be repeated. A salutary lesson has been learnt and all new proposals are subjected to rigid scrutiny at the hands of a committee appointed by Parliament.

A second danger is that owing to the absence of the salutary checks that act in the case of private enterprises, unduly expensive construction and wasteful management may exist. That such has been the case to a certain extent in the past is to be admitted. For example, the first portion of the northern system in Victoria, 101 miles long, cost over £5,000,000 without rolling stock. It is all double line, heavily ballasted with costly brick, stone, or iron bridges. There can be no possible doubt that had this been made a single line, with timber structures, and 1 in 40 grades instead of 1 in 50, a very large saving might have been effected, permitting either a substantial reduction in the heavy interest paid to the British bondholder, or an extension of the lines in other directions where they were much needed. However, this is an almost solitary case, and it occurred forty years ago. For the last quarter of a century railways have been made in all the States on fairly economical lines, and amounts varying from £2,000 per mile, in the case of pioneer lines in easy country, to £10,000 per mile, for heavy lines in fairly difficult country, have been usual. The average cost per mile in the various States up to date and the net earnings after paying all working expenses are as follow:—

COST AND NET EARNINGS OF AUSTRALIAN RAILWAYS.

	£ Cost per mile.	Net earnings per cent., deducting working expenses.
Victoria	12,300	3·07
New South Wales	13,700	3·63
South Australia	7,500	3·90
Queensland	6,900	2·67
Western Australia	5,000	5·81
Tasmania	8,200	1·11

As these are made with fares as low and often decidedly lower than those prevailing in Great Britain, and as the interest on the loans is 3½ to 4 per cent. only, the result may be regarded as satisfactory. Originally worked by an ordinary Government department with a Minister whose term of office was usually short, and who was exposed to much political pressure at the head, railway administration in Australia was in past years somewhat unsatisfactory. During the last fifteen years, or thereabouts, the railways have been usually managed with more satisfactory results by a Commissioner or Board of Commissioners, chosen for special knowledge and holding permanent appointments. The calibre of these gentlemen is evidenced by the fact that the Victorian Commissioner has recently resigned in order to take charge of the Midland Railway system in England.

To sum up, the Australian railways, though having their faults, like everything mundane, nevertheless constitute a most valuable public property, and an inestimable boon to the districts they serve. They are on the whole substantial, the number of accidents small, the fares moderate, the speed, considering all conditions, fair, thirty-five miles an hour on the narrow and forty-five on the broader gauges being usual on the easier parts of the lines; and the accommodation, on the main lines at least, up to date. The system of State ownership and management is universally approved, and the absorption of the principal private lines into the State system is generally expected in the near future. Without these railways the interior could not have been settled to anything like the extent it has, and the utilisation and development of the country would have been most seriously retarded.

Bibliography.

The following Papers in the Transactions of the Institution of Civil Engineers are of interest and value in connection with this subject:—Mr. E. Wood's Presidential Address, Vol. lxxxvii., p. 22; Burge on Hawkesbury Bridge, Vol. ci., p. 2; Kernot on Railway Construction, Vol. cxxix., p. 280; Stanley on Albert Bridge, Vol. cxxxii., p. 28; Burge on Railway Surveys, Vol. cxxxii., p. 302; Hales on N.E. Dundas Tramway, Vol. cxl., p. 154; Deane on Railway Construction, Vol. cxlii., p. 78; Jackson on Burdekin Bridge, Vol. cxlii., p. 253. The Annual Reports of the Railway Departments of the various States also contain much detailed and statistical information, illustrated by maps and photographs.

Considerable use of these has been made in compiling the present Paper, and the writer is much indebted to the officers of the Victoria Railway Department for giving him access to a large number of recent documents, collected from all parts of Australia and bearing upon the question in hand.

ARAFURA SEA
TORRES STRAIT
Cape Wessel
Cape Van Diemen
Melville Bay
Port Darwin
PALMERSTON
GULF OF CARPENTARIA
Groote Eylandt
Limmen's Bight
Sir Ed Pellews Group
Mornington I.
Bentinck I.
CAPE YORK PENINSULA
Cape York
Cape Grenville
Cape Direction
Cape Melville
CORAL SEA
NORTHERN TERRITORY
WESTERN AUSTRALIA
QUEENSLAND
SOUTH AUSTRALIA
NEW SOUTH WALES
ALICE SPRINGS
BURKETOWN
NORMANTON
CROYDON
GILBERTON
CLONCURRY
CHARLEVILLE
WINTON
MUTTABURRA
LONGREACH
BARCALDINE
EMERALD
ROCKHAMPTON
GLADSTONE
MARYBOROUGH
BRISBANE
Clarence River
GRAFTON
NEWCASTLE
SYDNEY
Botany Bay
GREAT AUSTRALIAN BIGHT
EYRES PENINSULA
ADELAIDE
Lake Eyre North
Lake Eyre South
Lake Gregory
Lake Blanche
Lake Torrens
Lake Frome
Lake Eyre
Lake Gairdner
Lake Macfarlane
Lake Everard
Lake Amadeus
Lake MacKay
Lake Nash
Lake Yamma Yamma
Lake Callabonna
Lake Victoria
Lake Cowal
Lake Bathurst
Lake George
Lake Bonney
Lake Albert
Lake Alexandrina
Lake Hindmarsh
Lake Wallace
Lake Wellington
Lake Tyers
Lake Tarra
Lake Colac
Lake Corangamite
Lake Purrumbete
Lake Bullen Merri
Lake Gnotuk
Lake Boga
Lake Charm
Lake Hattah
Lake Mulwala
Lake Victoria
Lake Cargelligo
Lake Brewster
Lake Cudgellico
Lake Urana
Lake Cowal
Lake Bathurst
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Lake Wallace
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Lake Tyers
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Lake Hattah
Lake Mulwala
Lake Victoria
Lake Cargelligo
Lake Brewster
Lake Cudgellico
Lake Urana
TASMAN SEA
SOUTH PACIFIC OCEAN
INDIAN OCEAN
BASS STRAIT
MAP
SHEWING THE PRINCIPAL
RAILWAY SYSTEMS
OF
AUSTRALIA
1899
SCALE
C.H. ENTESCHEL

DISCUSSION.

The CHAIRMAN : Although it was necessary to curtail the Paper, you have been able to follow perfectly well what Mr. Kernot wished to put before this meeting, and I shall be glad to hear any gentlemen discuss it.

I will, however, just say one word. It seems to me that the point of greatest interest is that which has caused anxiety over and over again in this and other countries, namely, the break of gauge. It was settled long ago in this country, and it seems to me that the Author's view is, that it would have been better for Australia if they could have come to some arrangement for a uniform gauge in that country. The question is not altogether an abstract one now, because it is arising every day in this country in connection with light railways. A great many advocates of light railways think they would be more profitable if a narrower gauge than the 4 feet 8½ inch were adopted. No doubt from an engineering point of view they could be more cheaply constructed, but if an estimate is made out for a narrow-gauge light railway and compared with that for the 4 feet 8½ inch gauge, it will be found that the saving in construction will be more than counterbalanced by the difficulty and inconvenience that will occur in transferring goods from the narrow to the broad gauge. That is the almost universal opinion of railway managers, whether it is or not of the railway engineers. Of course there are isolated cases in which it would be almost impossible, except at enormous cost, to construct a broad-gauge line, and therefore the narrow gauge must be adopted; but I am satisfied that in light railways it would be far better to adhere to the ordinary gauge, so that they can connect at one end or the other with the existing lines of railway.

I do not think I can say anything further in connection with this subject, and I will ask you to accord a hearty vote of thanks to the Author for the very valuable Paper he has presented to us. (*Carried by acclamation.*)

(*The Meeting was then adjourned.*)

PROCEEDINGS OF SEPTEMBER 5.

Mr. JOHN STRAIN, M.Inst.C.E., in the Chair.

[PAPER.]

THE PROPOSED TUNNEL BETWEEN SCOTLAND AND IRELAND.

By JAMES BARTON, Member of Council Inst.C.E.

THE great national as well as local advantages of a railway connection between Great Britain and Ireland are generally admitted, but whether considered in their commercial, social, or military aspects they do not form any part of the *Engineering* questions involved, and they are therefore not touched upon in this Paper.

SELECTION OF SITE.

The first question considered is the selection of site for the tunnel. There are three positions, speaking generally, which by the map suggest themselves :—

(1) The nearest approach of Great Britain to Ireland is at the Mull of Cantyre, where the distance between the shores of Cantyre and county Antrim is twelve and a half miles.

(2) The second position in point of distance is the projecting portion of Wigtownshire, west of Lough Ryan, where the Scotch coast comes within twenty-one to twenty-five miles of the coasts of the counties Antrim and Down in Ireland.

(3) The third position is that from Holyhead to Howth, in the county of Dublin, the distance here being fifty-two miles under sea.

The maximum depth of water on the Cantyre route is 462 feet; on the Wigtownshire route the depth varies according to the line selected, from 480 feet to 900 feet of a maximum depth; and on the North Wales and Dublin route the maximum depth is 432 feet.

The strata to be traversed, judging from the geological features of the approaches, are Lower Silurian throughout on the Cantyre route. On the Wigtownshire route, if to the county Antrim in Ireland, we have Lower Silurian on the Scotch side overlaid by New Red Sandstone, and that overlaid by Keuper Marl; if to the county Down, Lower Silurian throughout. The North Wales to Dublin route would be in the Cambrian rocks, with probably part in Gneiss.

The first of these three positions, however desirable as a first tunnel to Ireland from an engineering point of view, has to be abandoned on account of the great length of the necessary railway approaches on the Scotch side,

which on consideration is found to render it, practically speaking, a useless connection as between England and Ireland, and not a good one even between Scotland and Ireland.

The second route, lying as it does nearly due west of Carlisle, an important railway centre, and giving a direct line to Belfast, the most important business centre of Ireland, gives in the first place the best route of the three for Scotland and the North of England, both for business and pleasure travelling, as regards the whole of Ireland ; and secondly, it gives for the whole of Great Britain the best route for Belfast and the North of Ireland.

The third route would best connect London, and indeed the whole of England, with Dublin, the capital of Ireland, and through it with all Ireland ; whilst it would be practically of no value as between Scotland and Ireland, the railway access to North Wales being too long for a convenient Scotch route to Ireland.

If the third route had been but a little longer than the second, there might have been some doubt which should be attempted first, though at the loss of Scotch traffic ; but as the length of tunnel is more than double that of the second route, and as the tunnel, even by the second route, is nearly three times the length of any existing tunnel, the committee who have considered the subject, with the advice of Sir Douglas Fox and the Author as engineers of the project, have concluded that the second is the project to be attempted first. The success of the present project would go far towards assuring the success of the longer project to Dublin at a future time.

Location.

Coming, then, to the detailed question of location on the second route, all the earlier propositions made proposed the route Portpatrick to Donaghadee, which is the shortest and all in one kind of rock, as we believe, Lower Silurian. A physical difficulty, however, occurs on this route ; a deep valley or gorge called "Beaufort's Dyke," at the bottom of the sea, runs parallel to the Scotch coast, and some 7 miles from it, the bottom of which varies from 600 to 900 feet below low-water, and extends 30 miles from a point south-west of Corsewall Lighthouse, on the north, to a point south-west of the Mull of Galloway. North of this depression the bottom is comparatively level, the greatest variation from a horizontal line for 13 miles being 75 feet up or down.

To tunnel under Beaufort's Dyke would involve very long and deep drainage headings, and the lifting of all drainage water 300 feet more than by the route selected ; and would have to meet a very serious, and yet probable, danger of finding the bottom of the Dyke filled for an unknown depth with sea deposits laid down during the time which has elapsed since the ice age, at which period the Dyke may have been cut out. These contingencies appeared decisive against that route.

Description of Line.

The diagrams upon the wall show the route as selected in plan and section ; the line of the tunnel would pass round the head of the valley by a curve of a mile radius, which would suit very high speeds. (*See plan and section.*)

The approach line of railway leaves the Stranraer Railway Station and

passing north enters the tunnel at 5 miles, and descending 1 in 75 passes under the shore line at the Ebbstone Beacon at 9 miles; it passes round the curve at the head of Beaufort's Dyke at 16 miles, and runs thence to The Gobbins on Island Magee, co. Antrim, meeting the shore line at 34 miles, rising 1 in 75 from the deep water, through an approach tunnel to 39½ miles, where it comes out of tunnel and joins the Belfast and Northern Counties Railway at 41 miles, and by a third rail runs for 10 miles along it into the terminus at Belfast.

The total length from Stranraer to Belfast is 51 miles, of which 34½ miles are tunnel and 25 under the sea, and 25¼ from main shaft Scotch side to main shaft on Irish side.

In order to provide suitable drainage, the line falls from the centre each way towards the shores by gradients of 1 in 528. Drainage headings have to be run from the foot of the shore inclines at each side to the shafts where pumping stations would be placed. Subsidiary shafts at a short distance from the shore are shown upon the diagrams; these would, in connection with the main shafts, enable specially accurate lines to be given for the tunnel, which for so great a length and having a curve would need special precautions to ensure accuracy. These shafts might also be advantageous positions for pumping the water of the approach or land tunnels if it were found to be at all serious in quantity.

The geological aspects of the question are of very great importance and have been considered and reported upon by Professor Hull, who was for many years the Director of the Government Geological Survey of Ireland; and his views of the strata to be met with on the route are indicated and the probable inclination and thickness of the several rocks are shown upon the diagram section. Professor Hull's views were confirmed by the late Mr. Topley, of H.M. Geological Survey of London.

The top of the tunnel is proposed to be placed not less than 150 feet below the sea-bottom throughout.

The tunnel itself is proposed to be of rather capacious section for a double line of way, so as to give air space for high velocities and room for the best arrangement of electrical conductors.

To those present at the Congress who are not familiar with tunnelling, it may not be superfluous to say that the driving of headings, or drifts, from the main shafts on either side of the channel is not only the first, but the principal operation in the construction of such a tunnel, as controlling the time of execution of the whole work and involving the mastery of its difficulties, both as to material of strata, water, and speed with which the heading can be driven through.

The dimensions of the proposed main heading will be 10 feet wide by 7 feet high. The widening to the full size and the lining of the tunnel can be carried out so much more rapidly that the whole work may be completed probably within a year after the headings are through. The headings through the Silurian we think should be as rapid as those now proceeding in the Simplon Tunnel; those in the Keuper Marls more rapid, and the whole, if favourable, might be completed under 10 years, and the tunnel opened within 11 to 12 years. It may be that we will be able to still further shorten the time, if special difficulties do not arise to delay the work.

Tunnelling Up to Date.

There are few branches of engineering in which such remarkable advances have been made lately as in tunnelling. The tunnels in London clay, and in soft strata in America, with iron lining, are the result of one branch of tunnel work having been brought to considerable perfection; but whilst the shield will not be of any value to those working at the pressures to which this under-sea tunnel is exposed, it is quite possible that iron or steel arching may be adopted in short lengths to take the whole static pressure of particular leaks, and so save pumping.

The advances in rock drilling and tunnelling in the Alpine tunnels have been remarkable in late years. The maximum speeds in pushing forward the Alpine tunnels have been as follows, and the cost per yard forward of tunnels complete is given as below :—

	Maximum speed per day.	Cost of Tunnel per yard complete.
Mont Cenis Tunnel	6 yards	£224
St. Gothard Tunnel	10 yards	£142
Arlberg Tunnel	12 yards	£107

The Simplon headings have exceeded the speed of the Arlberg, and that in a very hard rock—hard schist with quartz veins; I have been able to obtain samples of it taken within the last month 5 kilometres (3 miles) in from the face at the Brigue end, which I submit with this Paper, as also specimens of the Marl and Sandstone from Antrim and Silurian from Wigtownshire on the line through which the proposed Channel Tunnel would pass.

The cost of the work and the speed in the Silurian would probably be similar to the Simplon, whilst both the Keuper Marls and Sandstone would probably be much quicker and less expensive.

The Water Question.

The amount of water to be dealt with is the one uncertainty; we have, however, grounds for believing that it is not likely to be a very serious difficulty.

In the first place, in the case of both the Severn and the Mersey Tunnels no large water leakage was encountered *under the sea*, the great Severn leak being fresh water and a quarter of a mile from the sea. This view is confirmed in the case of a tunnel driven for some distance under the River Forth by Sir Benjamin Baker, giving good ground for believing that the sea-bed under the Irish Channel, which is generally covered by a slimy ooze, has throughout the ages during which it has been undisturbed gradually sealed all interstices, so that excavation sufficiently low may be expected to be fairly dry. Moreover, the water difficulty of the Severn Tunnel occurred in limestone strata of the coal measures, where fissures and underground channels are not uncommon; no such rocks are, in the opinion of Professor Hull and others, to be found in the Irish Channel, and the Silurian on the Scotch side, through which the tunnel will pass for 25 miles, is found in beds nearly vertical, squeezed, and contorted by pressure to such an extent that they are very close in stratification, and probably will give little water either in the under-sea or in the approach tunnel on the Scotch side.

The Keuper Marls as found on the Irish side all through the approach

tunnel, and probably extending some four miles under the sea, are remarkably suited to an under-water tunnel, being perfectly watertight down to a depth of 950 feet, to which depth a shaft has been sunk through them and which is perfectly dry; these marls whilst easy of excavation and homogeneous are yet so far solid as to stand unsupported some 50 to 60 feet wide, and carry a thickness of 800 feet between them and the surface. The New Red Sandstone is found in co. Antrim and co. Down near Belfast, between the Keuper Marls and the Silurian, and so presumably upon the line of the tunnel; it is shown upon the diagram in the position and of the thickness estimated by Professor Hull.

This rock allows water to percolate, but it is not likely to give any large quantity except it be at its junction with the Silurian, where, if the sea-bed is not sealed as we anticipate, there may be a good deal of water, though not in such quantity, according to Professor Hull's report, as to be likely to prove any serious difficulty.

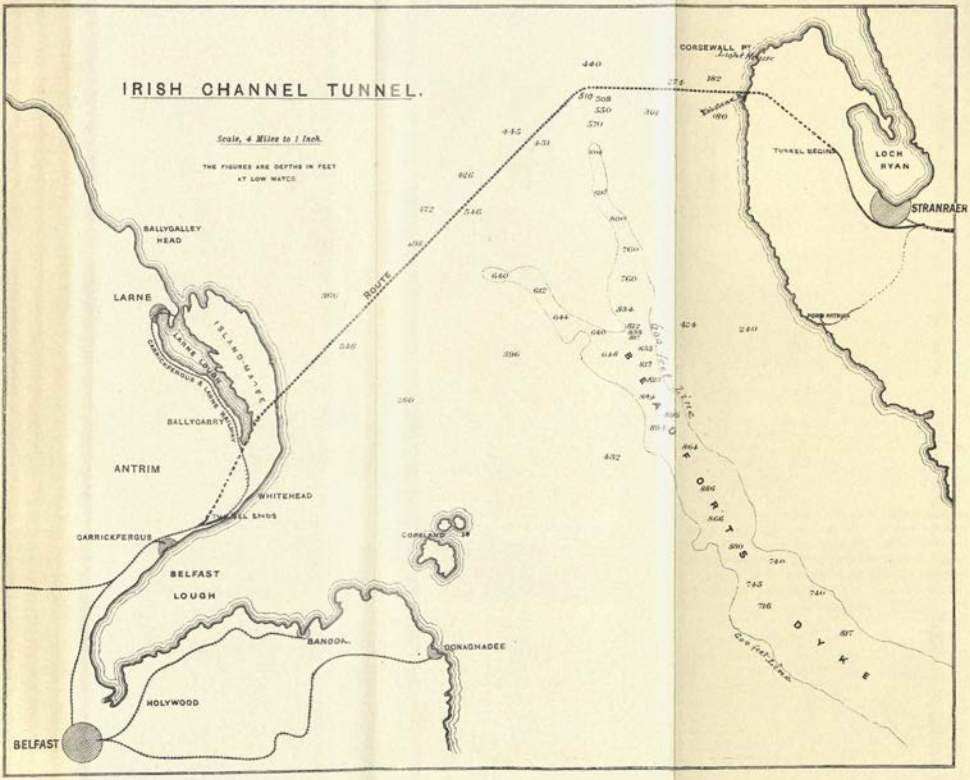
The *primâ facie* difficulty of dealing with water at a depth of 150 to 200 feet below the sea-bed, or, say, 750 feet below low-water, is the pressure under which it would be; but as we propose placing the level of the top of the tunnel at a minimum of 150 feet below the sea-bed, the water would have to percolate through that depth, and would issue probably at a small pressure. The whole question of difficulty is probably confined to this: will the total quantity of water to be dealt with prove too large for pumping at a cost which, capitalised, would seriously add to the cost of the tunnel, as estimated? And if a large leak occurred, could it not be met by iron or steel arching for a short distance, or by a deviation to go round the leak? Precautions can be taken to prevent danger from a sudden influx of water, and we believe that leaks, even if beyond the amount we anticipate, can be so met and are not such a difficulty as should, in the light of the experience of the Severn and Mersey Tunnels, cause any hesitation.

Working.

The working of the tunnel and the line from Stranraer to Belfast is proposed to be by electric motors, from two installations, one near the main shaft at each side of the channel. There seems no reason to doubt that trains can be run regularly at a speed of 60 to 70 miles per hour through the tunnel, so that the time occupied in passing through it would be about half an hour, and the whole distance from Stranraer to Belfast, being without intermediate stops, could be done regularly under the hour.

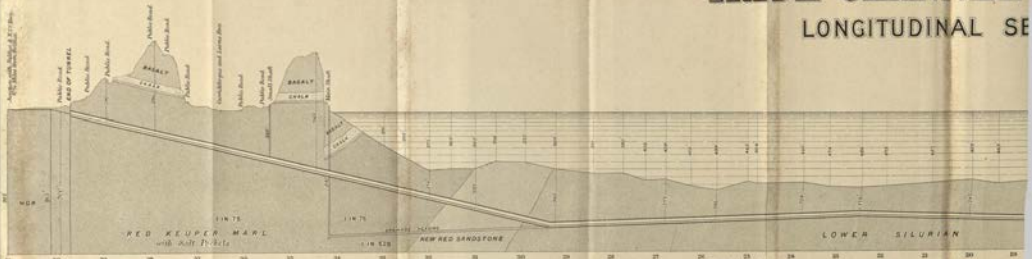
Ventilation.

The ventilation of the tunnel after completion is, by the use of electric power, made comparatively easy. The products of coal combustion are the difficulty in all ordinary tunnels. Fans to send in a current at one end and draw it out at the other would set up a constant current in one direction, and probably be quite sufficient. A mode of inducing a current in a tunnel with open ends has been worked out satisfactorily in Italy by the Saccardo system, which is on the principle of the injector, the air being sent in through an annular chamber, formed round the tunnel near the entrance, and passing


IRISH CHANNEL TUNNEL.
Scale, 4 Miles to 1 Inch.
THE FIGURES ARE DEPTHS IN FEET AT LOW WATER.
CORSEWALL PT.
Light House
TUNNEL BEGINS
LOCH RYAN
STRANRAER
BALLYGALLEY HEAD
LARNE
ISLAND MAGEE
LARNE LOUGH
CARRICKFERGUS & LARNE RAILWAY
BALLYCARRY
ANTRIM
WHITEHEAD
CARRICKFERGUS
BELFAST LOUGH
COPELAND
BANGOR
DONAGHADEE
HOLYWOOD
BELFAST
ROUTE
NORTH CHANNEL
IRISH SEA
DOG'S DYKE
Low Water Line

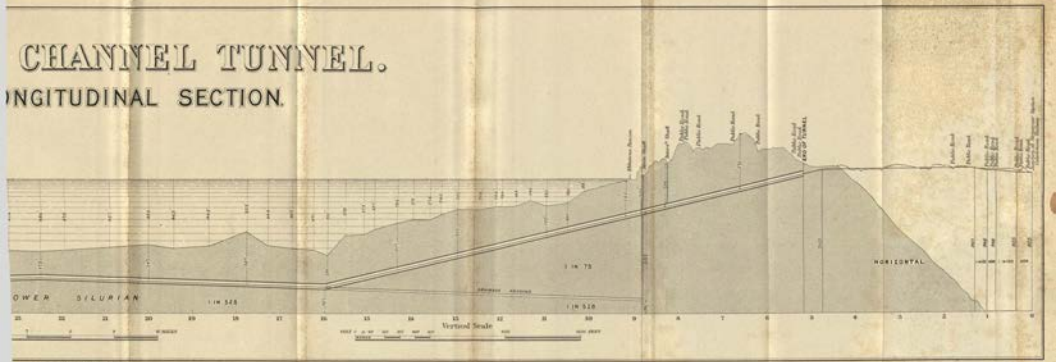
IRISH CHANNEL

LONGITUDINAL SE


Public Road
END OF TUNNEL
BASALT
DYKE
Public Road
Public Road
Public Road

CHANNEL TUNNEL.

NGITUDINAL SECTION.



into the tunnel in a thin cylindrical form, thus drawing in and sending forward the air from the outside, the reverse operation at the further end sending the current outwards.

The provision of power for drilling the rock, as well as moving the wagons of material during construction, would probably best be attained also from electric motors, and there seems little doubt that through the Marls on the Irish side and Sandstone, if not through the Silurian rocks, large excavating drills to form the whole heading, 8 or 9 feet diameter, in one operation, may be constructed capable of doing even more rapid work than by the use of explosives. Large water and air pipes, under pressure, would also be necessary in the construction of the heading, and would have to be carried in from the outside, for the supply of the men as well as for the work.

Estimate.

The cost of this tunnel has been estimated by the engineers and by a contractor at ten millions, exclusive of interest during construction; this sum is estimated on a liberal basis and leaves a considerable margin for contingencies.

This Paper, though coming before an Engineering Congress, would not give a definite view of the project without some note of the financial aspect as being the present difficulty. As far as ascertained the probable traffic would, with a mileage allowance of two miles for one by the railway companies, pay 3 per cent. dividend a few years after the opening; but this is not such a prospect as would enable the money to be found as a speculation, and the committee having charge of the project have laid the matter before the Government to seek their aid.

Mr. Balfour received an influential deputation of peers and members of Parliament on the subject of giving a guarantee on the capital, and expressed himself desirous of seeing the project carried out, and, subject to the amount of capital being in some way fixed, he was willing to bring the subject before his colleagues.

The project is too large, and subject to too serious contingencies, to be contracted for as a whole for a fixed sum at present, but if shafts were sunk on each side and a heading run from the Irish side so far as to pass the junction between the Silurian and the Sandstone, it is probable that this difficulty would be overcome. This can be done for half a million. A heading through the whole tunnel and approach tunnels is estimated at two and a half millions.

LIBRARY OF THE BOMBAY BRANCH OF THE ROYAL ASIATIC SOCIETY

DISCUSSION.

Mr. JAMES MANSERGH[1]: It was quite by accident that I came in when Mr. Barton was reading his Paper, and I did not expect to take part in the discussion. There are, however, two points to which I should like to refer. I have recently been driving 10 or 12 miles of tunnel in Silurian rocks, and in some of them a great deal of water has been met with. I quite agree with Mr. Barton that probably under the sea the surface may be covered and the interstices in the rocks filled with material, which will prevent water from passing downwards. I think, therefore, it is very likely that there will be less water in a tunnel of this sort than in one which is not under the sea. I notice by the section on the wall that the drainage heading on one side is 5 miles in length, with a fall of 1 in 528 towards the pumping shaft, or 50 feet in the 5 miles. As the heading must be big enough for men to work in, say 6 feet 6 inches high by 4 feet 6 inches wide, much less fall than 10 feet per mile would suffice for all the water that is likely to come in. Probably 2 feet per mile would be ample; if so the drainage shaft would be 40 feet less deep, and the pumping lift would be similarly diminished. On the other shore the drainage heading is longer than 5 miles, and therefore the saving would be correspondingly greater.

Mr. F. W. MCCULLOUGH: The Author at the outset states that for a number of years past a great deal of interest has been taken in this subject. As far back as 1886 I took considerable interest in investigating the schemes for a Channel Tunnel, which were in existence prior to that time. After examining into a number of new routes that appeared to me to be quite feasible, and which, moreover, were in the district of Mr. Barton's present scheme, I brought the matter before the public, in the press of Ireland, England and Scotland, early in 1890. At that time I mentioned the new routes, which I had investigated in a preliminary way, from the north point of Island Magee, where the words "Larne Harbour" are marked on the map, to Corsewall Point in Wigtownshire, also from Muck Island to Portpatrick; but after examining the details of these particular routes, and finding that there were many serious difficulties in the way, I then came to the conclusion that a scheme since known as the "Whitehead and Portpatrick scheme" was the best. That scheme dips under the sea at a point marked Blackhead, in Island Magee, and joins the Wigtownshire coast within about 3 miles north of Portpatrick. At that time the only other scheme for an Irish Channel Tunnel that was before the public was one from Donaghadee to Portpatrick, connecting county Down in Ireland with Wigtownshire in Scotland, and the only other tunnel scheme was further north, as mentioned by Mr. Barton, which provided for the connection of the county of Antrim with the Mull of Cantyre, and which has always been known as Mr. Macassey's scheme.

I claimed then, and claim still, to be the author of the first tunnel scheme suggesting a connection between the county of Antrim in Ireland and

[1] President of the Congress.

Wigtownshire in Scotland. Shortly after working out the particulars with reference to the proposed routes which I was considering between Antrim and Wigtown, my friend Mr. Barton suggested through the morning papers of Belfast that he also was examining the question of an Irish Channel Tunnel scheme between Ireland and England, and that he would shortly bring the details before the public. That was the first time anyone had suggested the possibility of making a Channel Tunnel between Ireland and England. That, to my mind, suggested that Mr. Barton, at the time referred to, had really no details prepared for any scheme; and this conclusion is borne out by the reference he now makes in his Paper to the proposed scheme between Howth and Holyhead. Strange to say, in answer to a letter addressed to him at that time by a correspondent, expressing surprise at the proposal of making a Channel Tunnel between Ireland and England, the editor of one paper stated that the word "England" was a clerical error; while the editor of the other paper pointed out that it was a printer's error.

Now, I say that in dealing with a large question like the present one, it is only fair and reasonable that any scheme suggested for crossing the Irish Channel should be fully and fairly compared with all other schemes already in existence, and also I hold that no individual should seek credit for introducing a scheme which is really a borrowed one. If you look at the map showing the lines of the proposed routes, you will see that the one now suggested by Mr. Barton is entirely situated within the limits of the schemes mentioned for the first time publicly by myself in 1890. Ten months elapsed before Mr. Barton was able to bring forward the details of his scheme—which was very much the same as his present one—before a meeting called under the presidency of the Lord Mayor of Belfast. At that time, strange to say, the length of the sea tunnel of Mr. Barton's route was given as 26½ miles, whereas I find by the Paper which Mr. Barton has so ably brought before us to-day that the length of the marine tunnel has now shrunk to 25¼ miles. If the tunnel were shortened by 1¼ miles it should have the effect of bringing it into slightly deeper water than the original scheme, and under ordinary circumstances the ruling gradient would be increased. I find, however, that the ruling gradient of the present scheme is somewhat the same as the ruling gradient of the scheme which Mr. Barton brought before the public meeting at Belfast in October, 1890. I notice also that in the present Paper now before the meeting, Mr. Barton has only compared some of the general details of his scheme with the Cantyre route, as well as the older route between Donaghadee and Portpatrick, but also that he has carefully avoided any comparison whatever with the "Whitehead and Portpatrick scheme." In fact, it is suggested in the paper that all the earlier schemes proposed were in the neighbourhood of the Portpatrick and Donaghadee route. I join issue with Mr. Barton at once on this point, because it is well known, not only to Mr. Barton, but to all those who have taken an interest in this big question, that the details of the Whitehead and Portpatrick scheme were made public through the press of the kingdom some ten months before Mr. Barton's scheme was brought forward in 1890. A very able paper was read before the Society of Arts in 1891, by Sir Roper Lethbridge, on the "Irish Channel Tunnel," when all these schemes were fully compared; and I am pleased to be able to say that the Whitehead and Portpatrick scheme was very favourably

mentioned on that occasion. In a very able article written on the Irish Channel Tunnel, by Mr. Ferguson Walker, in the *Contemporary Review*, he deals very fully with the various schemes, and concludes that the Whitehead and Portpatrick route has many advantages over any of the others. Going shortly into the general details, without taking up the time of the meeting, I may mention that the length of sea tunnel by the Whitehead and Portpatrick route is 23½ miles, which would be 2 miles shorter than Mr. Barton's present scheme, and is a very important advantage in a project of this sort. The approach tunnels on the Whitehead and Portpatrick scheme would be 3½ miles additional, which make the total length of the land and sea tunnels 27 miles; whereas the total length of Mr. Barton's scheme, according to his Paper, is 41 miles. As the whole length of the line by the Whitehead route is only 31 miles, and by Mr. Barton's present route 41 miles, there is still a difference of 10 miles in favour of the former route. The ruling gradient in Mr. Barton's scheme is 1 in 75, while in that of the Whitehead and Portpatrick scheme it is 1 in 58. I therefore hold that the latter scheme has many important advantages over Mr. Barton's longer route, because it should be more easily constructed; for whatever applies to the strata in Mr. Barton's scheme is applicable to the Whitehead—Portpatrick scheme, both being so closely situated. The greatest depth of water on the Whitehead and Portpatrick route is 650 feet, as compared with 450 feet on Mr. Barton's, and that only affects the question generally in the matter of gradient. I consider that 1 in 58 is not an extreme gradient, inasmuch as I have travelled over a number of railways here in Scotland and other parts where at places there are gradients of 1 in 45, and even steeper, which work very well.

As Mr. Barton has stated, electric traction does not affect the question very much; but, as I have said before, the difference of three miles in the total length of the sea tunnel in the two routes is a matter which must give the Whitehead and Portpatrick scheme a great advantage over Mr. Barton's project—not only as regards cost, time of construction, ventilation and pumping, but also on account of the difference of about 11 miles in the total length of the two routes; and no matter where you are going to, whether from Belfast to Scotland or to England, this 11 miles must always be in favour of the Whitehead and Portpatrick route. Until some more definite knowledge is obtained with regard to the geological difficulties to be contended with in each of the schemes referred to, I hold that with these advantages in favour of the Whitehead and Portpatrick route, it is a preferable scheme to the one now described in Mr. Barton's Paper.

Mr. LEONARD M. BELL: For some years I have taken a great deal of interest in this subject, and I think it would have been an advantage if the Author had given us further figures as to the rate of progress in construction which might be expected. I have recently been in charge of some 6 or 7 miles of tunnels through the Silurian rocks in connection with the Mourne Waterworks, and, from the rate of progress we have made there, I have very grave doubts as to whether Mr. Barton could cut his tunnel at the rate he mentions.

Sir DOUGLAS FOX: Would you give us your rate?

Mr. LEONARD M. BELL: About 2 yards per day would be the average for this class of rock.

Sir DOUGLAS FOX: What size is the face?

Mr. LEONARD M. BELL: The face is about 8 feet by 8 feet. The Silurian met with is a hard indurated rock, and it is difficult to make rapid progress in driving. In one of our tunnels of 2 miles in length, the average rate of progress was 10 yards per week, year in and year out; but probably Mr. Barton, with the newer tools he refers to, could get on faster.

Sir DOUGLAS FOX: Were you working with drills?

Mr. LEONARD M. BELL: We were working with compressed-air drills.

With regard to the water met with in this class of rock referred to by Mr. Mansergh, who said "we have had a great deal of trouble from water coming down," I sincerely hope that the fissures will be found silted up, as suggested by Mr. Barton. The fissures which we have found in our tunnels have generally been vertical, extending sometimes 150 or 200 feet upwards, with a good run of water occasionally. It has been said that in the Severn Tunnel and in the London Tunnel very little trouble was met with from water coming through the bed of the river. That is so; but I think we should have regard to the fact that in London tunnels the strata appear chiefly to be more or less horizontal, so that only a little water came through. In fact, in one tunnel under a river on which I was engaged, we had absolutely no water in places where we expected a considerable amount, while in other places under the land a good deal occurred when none was expected.

As to the gradients of 1 in 75, I may mention that in the Swiss tunnels much heavier gradients—something like 1 in 50—are adopted. As this scheme will have to be worked with special locomotives or special electric engines, I do not think the heavy gradients will matter; and having regard to the fact that the line would be worked by special locomotives, would it not be wiser to go to a greater depth than 150 feet below the surface, so as to lessen the risk of an inrush of water? As to tunnelling through the Keuper marl, I have been in charge of two tunnels through that substance, the greater part of which was soft marl, but intersected by basalt dykes; and in these places we had a great deal of trouble, due to the water coming down through joints in the clay or marl where it had been indurated and cracked into rough blocks, like loose bricks, by the molten rock being forced up through it. The marl on both sides of all the dykes was cracked in the way I have explained; at places not intersected by dykes there was absolutely no water, and, as Mr. Barton has said, it is perfectly dry; but you have the other trouble of the swelling of the clay. I should be afraid that, instead of making quicker progress through the marl, it would probably be slower than the Silurian, as the tunnel lining would have to be put in as soon as possible after the ground was opened, and the advance heading could not safely be driven faster than the full tunnel behind was being lined. The rate of advance would thus be restricted, as if the advance heading lay too long the clay would swell and the heading would collapse; I have seen such tunnels come in and cause an immense amount of trouble from lying too long.

It has occurred to me in this connection that it might be wiser to drive a

tunnel in two tubes or cylinders, something in the same way as the electric railways are now being driven underneath London. Supposing a dyke with water were met with in the tunnel, probably only one tunnel would be flooded out; while with the other tunnel it might be possible, with great care, to get round and pass one of these leaks. It therefore appears to me to be a question worth consideration whether it would not be wiser to work with two independent tunnels instead of a large single one. In the Severn tunnel, which is a double-line tunnel, 26 feet span, it has been found that the brickwork will not stand the hydrostatic pressure of the water; with two smaller tunnels with steel or iron linings, I think it would be possible to make it strong enough to resist the outside pressure. I have not gone into the figures of the strength of the iron or steel lining necessary, but I think it would be wise to adopt some such means to get over difficulties with the water, which would certainly be met with. We have the risk of a great influx of water, and we do not know where or when it will come. Would it not be wise to meet a difficulty of that sort boldly by providing a suitable lining?

I think Mr. Barton is to be congratulated on his very interesting and instructive Paper.

Sir DOUGLAS FOX: I should like it to be understood that the great amount of research which has been carried out in connection with this proposal is due entirely to Mr. Barton. He was kind enough to consult me two or three years ago, and since that time I have taken a deep interest in this very important question.

The financial point is *the* crux of the whole matter, and of course that is a question which we need not discuss here. This is a national work, and I think none will deny that it is one of Imperial importance. I believe the influence produced by the union of the two countries will be very great, and from the position of this tunnel it really connects those two centres, Glasgow and Belfast, which most desire to be connected. Not only is it the natural place to cross, but, from a commercial and national point of view, to connect the two countries in a direct line between Belfast and Glasgow is the most important that can be selected.

I should like to refer to the very practical remarks made by Mr. Bell. Although at the present moment the suggestion is that a double tunnel should be adopted, I think there is much to be said worthy of consideration as to the desirability of adopting some analogous system to that carried out in the Simplon Tunnel, namely, two single tunnels, with a heading between. That, however, is after all a matter of detail, and I think we have a much more important question to consider before that. I should like to say a few words on the subject of speed of construction. Mr. Bell told us that he had been working in Silurian, and that the progress was very small, namely, 2 yards per day, or 10 yards per week. That may be perfectly good progress with a small plant, but the whole question of speed depends on the making of thoroughly good arrangements as to plant, and putting plenty of power into it. We have now the practical result, which Mr. Bell may not have heard, in connection with the Simplon Tunnel, that the rock, which is the hardest I have ever seen, is being steadily disposed of in that heading at the rate of

22 feet per day. (*Applause*). That is a larger heading than the one mentioned by our friend. Therefore I think we may fairly assume that by the time this tunnel between Scotland and Ireland is sanctioned—which I am afraid will not be this year—we shall attain an even better speed than this, because there has been very great progress in tunnelling since the day I first had any connection with it; what we thought was rapid progress at that time is now considered quite a snail's pace. A continuous speed is maintained in the Simplon Tunnel, and my brother, who is there now, informs me that in the passage, which is about 11 feet by 8 feet, they are proceeding at a little more than 22 feet per day at each face. With reference to the question of Keuper marl, I had the pleasure of visiting the site, going down the shaft, and examining the strata with Mr. Barton, and I think that Keuper marl will present very great facilities for rapid speed; I should prefer it to be a little softer than the specimen shown here. We have had great experience in London of late years in working through soft strata; our clay in London is very hard until you expose it to the atmosphere, as Mr. Bell suggested might be the case with Keuper marl. We find that by using a shield we entirely overcome the difficulty, and we have been making a speed in London of about 12 yards per day; so that if you take the Silurian at something like 6 or 7 yards, and the other at 10 yards, you bring the progress of the tunnel down to about eight or nine years to complete. Therefore I do not think that ten years is too short an estimate for the time in which the tunnel will probably be completed. There is one great advantage, as Mr. Bell suggested—and I always like to meet a fair suggestion—in using two single tunnels. A 16-feet shield is much more portable and easy to deal with than a shield for a double tunnel of, say, 27 or 28 feet in diameter; that is a matter of detail, though important.

With reference to Mr. McCullough's remarks about Mr. Barton, I do not wish to go into a personal question such as that; I think such questions are rather out of place here.

I cannot understand in the least how Mr. McCullough, who has had, I am glad to find from his position, very considerable experience with reference to water-bearing strata, can select a route from Whitehead to Portpatrick. It appears to me to get into the very difficulty which we certainly ought to avoid. Of course it would be very pleasant if we could run from Donaghadee to Portpatrick in a straight line; and it would be very pleasant if we could start from Blackhead and go straight across to Stranraer without the curve shown in the proposed tunnel. But I am strongly of opinion, from experience in tunnelling under the Mersey and elsewhere, that it would be a very risky operation to go across that chasm which has been ploughed out in the bed of the sea, and that it is far better that Mr. Barton, with that caution which he has learned from experience and mature age, should have avoided that difficulty, and gone round the northern head of the rift. There we have a solid bed, and, as Mr. McCullough stated, we have 200 feet less water. I am quite convinced that it would be unwise to cross that rift in the bed of the channel either from Whitehead or from Donaghadee.

The suggestion of making a tunnel from Ireland to England may probably take some people's breath away, but it does not frighten engineers; it is only a question of length. As regards difficulty, in my opinion it is a much

simpler process than that which we had to face when we had to cross the Mersey, and I will tell you why. In the case of the Mersey we had sandstone full of water, It is an interesting fact, and I should like to mention it here, that what Sir John Fowler prophesied in the case of the Mersey came true. When they were attacking his Bill, Mr. Bateman, the engineer, said that it was absolutely impossible to cross the Mersey, because there were very large faults in the sandstone, and that the water would come in to such an extent that they would not be able to deal with it. Sir John Fowler stated in his evidence that in his opinion no water would be found in these faults; that was considered to be a very bold statement. His Bill did not pass, but we carried a Bill through for a similar work, and our experience fulfilled his prophecy. I, personally, like to prophesy after the event; he prophesied before, and showed how wise he was. In fact, the driest places we met with in our tunnel were those very faults; there were a great many of them. Whilst the water forced its way through the porosity of the sandstone, it did not pass through those faults; we had sandstone which was full of water, and we only had twenty-five feet of cover at any point between the roof of our tunnel and the bed of the river. So far from the bed of the river being covered with slimy ooze, as Mr. Barton tells you is the case with the bed of the Channel, the rock for a considerable distance across the Mersey is always bare, so that ships cannot anchor there; not only so, but in consequence of certain difficulties arising in connection with the Pluckington bank it was quite impossible to get borings down to see where the rock was on the Liverpool side. We thought we had twenty-five feet of cover; but, as a matter of fact, we ran out into the silt of the river, which was a mixture of sand and ooze. We knew there was a doubt about it, and the consequence was, when we came there, we drove a top heading in very short lengths and kept a watch upon it. But, curiously enough, we met with hardly any water when we got out of the rock; the water which you see pumped from the Mersey comes generally from the sandstone, owing to its porosity, and chiefly from the land.

So far as we can ascertain, no water finds its way direct from the river; it is very slightly brackish, and that is all you can say for it. The difficulties in that case were, as I have said, much more serious to contemplate than in the case of the proposed tunnel, though there is the disadvantage of its great length; that, however, is only a matter of expense and time. I would face the proposed scheme with much more composure of mind than I did when I looked across the Mersey and knew what we had to deal with there. We are not now any longer able to obtain the very valuable opinion of my old friend Sir James Brunlees, who was my right hand in the Mersey work. Still, we have the experience of many other people since that time; and I am quite sure that this tunnel can be driven with as great facility, if not greater, than either the Severn or the Mersey Tunnels.

With regard to cost we are now in possession of the cost of a great many tunnels; I will not repeat the figures given in the Paper. In a letter which appeared in the *Times* last week, we were told what the cost of the Simplon Tunnel has been up to the present time. It says: "The total cost when both tunnels are completed will be about £60 per lineal yard of single-line tunnel." That would mean, if we made two single tunnels, as Mr. Bell suggested, that the proposed tunnel would cost £120 per yard. But a good deal of our work

will be through material which is not going to be anything like so expensive as work through the Simplon rock, which is full of quartz, and is about as hard a material as you can possibly find. I think the results attained are very wonderful, but I have not time to go into the reasons. I am very sorry my nephew Mr. Charles Beresford Fox is not here to-day, but I should like to refer gentlemen who are specially interested in this very important question of rapid progress in speed in tunnels, to a paper read by him before the Institution of Civil Engineers, entitled "The Construction of the Simplon Tunnel." He was there for some time, and he has described very fully what took place up to the time he left. You will not, however, find the latest information in that paper as to speed, because it was read in 1900. I am quite convinced, if we have the opportunity of driving our heading here, that we shall reach even a much higher speed than that which we are talking about. I do not know whether the gentlemen present are aware that in the case of the Mersey, the drainage heading was driven two-thirds of the length by what was called Beaumont's machine; that was through red sandstone. But I have no doubt that with our present knowledge we shall be able to adopt a machine for driving the drainage heading; and if we can do that we shall both expedite the progress and reduce the cost.

I am sure we all feel that Mr. Barton has brought this matter up before us in a very complete form, and I think, not merely from an engineering point of view, but from a national point of view, this work will be one of great importance. (*Applause.*)

Prof. C. A. CARUS-WILSON: I cannot agree with the suggestion made by a former speaker that it would be wise to increase the grades on the existing design; the grades of 1 in 75 already there are a more serious matter than might at first sight appear. High speed in this proposed scheme is evidently a great feature, and Mr. Barton has spoken of an attempt to get an average speed of 60 miles an hour. I hardly need point out that a speed of 60 miles an hour up a grade of 1 in 75, with, say, a 100-ton train, counting the weight of the train only, means a locomotive of between 800 and 1,000 H.P. I question if it would be economical to go at 60 miles an hour up that gradient. The speed would probably have to be reduced; any attempt to increase the gradient would still further seriously affect the speed. Another point in connection with speed is the fact that the break in the straight, as shown on the plan, comes at a very awkward place—just at the foot of the long grade from the Scotch side.

Sir DOUGLAS FOX: It is only one mile radius, and it is very flat.

Prof. C. A. CARUS-WILSON: Trains would get up a very high speed in running down that side, but the speed could hardly be increased much beyond the sixty miles an hour on account of that curve; it therefore seems to me to be very important not to limit the speed in any other direction.

Sir DOUGLAS FOX: I should like to say that the introduction of steep gradients would not help us from a constructive point of view. The mile radius shown there is the curve we adopted on the Great Central Railway, on which our trains frequently run at 80 miles an hour; therefore there is no doubt that speed might be attained in this case.

Mr. JAMES BARTON: Our President, Mr. Mansergh, in his remarks called attention to the fact that the gradient of 1 in 528 carried on for a drainage heading was, in his view, more than would be absolutely necessary for the water-fall with the size of drainage heading that would probably have to be made; that is a suggestion upon an important detail for careful consideration.

I hardly think there is any occasion for me to reply to Mr. McCullough's remarks as to his personal part in this matter, but I should be very sorry indeed that anything in my Paper should be construed as taking from anybody any special credit they might deserve. I know that at the public meeting in Belfast which Mr. McCullough alluded to, a committee of leading men was formed, and Mr. McCullough and others who spoke were asked to bring their views before the committee who were to deal with the question. That committee has since formed a committee in London as well as in Belfast, and the joint conclusion which these committees, together with a number of Members of Parliament, came to was the adoption of this proposed line. But any suggestion, even now, that can be made by Mr. McCullough or anybody else will, I have no doubt, receive the most patient and careful consideration from those gentlemen. Mr. McCullough suggested that there was a shallow point across between Whitehead and a point in Wigtownshire where he could cross at a depth of something like 650 feet, but when that came to be investigated it was found that the chart was imperfect, and did not give the full number of soundings that have been made; in fact, there was no such point in this dyke which could be crossed at 650 feet or anything approaching to it. I did not quite gather where the headings were situated which Mr. Bell referred to as being worked at 2 yards a day.

Mr. LEONARD M. BELL: The Mourne Waterworks tunnels.

Mr. JAMES BARTON: They are a good long way from this place, and this geological map does not indicate that it is the same rock at all.

Mr. LEONARD M. BELL: The works extend from the point you mention to Belfast.

Mr. JAMES BARTON: It was a small tunnel for the waterworks?

Mr. LEONARD M. BELL: It was an 8 by 8 heading, mainly through the Lower Silurian.

Mr. JAMES BARTON: That is not very far short of what this would be. If your rock were compared with these specimens from the Simplon Tunnel I have no doubt you would find that these are fully as hard, if not a great deal harder. I understand that electrical drills have accomplished the most rapid work in the headings of the Simplon Tunnel, but the detail of how it is obtained is not of so much importance as what advance a day at the face has actually been accomplished. We have heard that the rate of 22 feet 10 inches has been reached, and I have received a rather higher figure since that report from the Simplon Tunnel.

The important points brought forward by Mr. Bell have been dealt with by Sir Douglas Fox, and I need therefore not allude to them further.

The CHAIRMAN: Before asking you to accord a vote of thanks to Mr. Barton for his most interesting Paper, I would only say that whatever our views may be, whether pessimistic or optimistic, with regard to this

project, the enormous advantages of such a scheme as this, whether viewed from a social, political or commercial aspect, cannot be overestimated.

If this tunnel were made, Ireland would be connected with this country for all practical purposes in the same way as England is connected with Scotland. The scheme may shortly be called the readiest means of bringing to a successful issue what has troubled the political parties in this country for many years—I would call it an engineers' solution of the Home Rule question. (*Applause.*) I think it would do more than anything else to cement the three countries together. I ask you to accord Mr. Barton a hearty vote of thanks for his very able and interesting Paper. (*Carried by acclamation.*)

Mr. JOHN STRAIN, M.Inst.C.E., in the Chair.

[PAPER.]

CHEAPER RAILWAY FARES.

By HORACE BELL, Member of Council Inst.C.E.

ON no subject is opinion so frequently and strongly expressed, both in private and in public, than on the need for cheaper railway fares. It cannot be contended that this is mere British grumbling, since, if it means anything at all, it implies that, on existing conditions, the mass of the people cannot afford to travel as often as they would do on more reasonable terms, or, in other words, on terms more suited to their means. The question is one mainly of third-class fares, for it is from this source that quite 90 per cent. of passenger receipts are derived at the present day. The second class must be regarded as a moribund institution, while the first class is on most lines unremunerative, and is maintained, in great measure, as a politic concession to a small but influential body of customers. The movement in the direction of one class is already well defined. Its complete success, coupled with low fares, on tramways, on omnibus routes, and lately on the Central London Railway, affords unmistakable signs of what we are coming to in the near future in serving nine-tenths of the travelling public. Yet, in spite of these and other obvious indications of change, our home railways still adhere stubbornly to the "Parliamentary" minimum fare of one penny per mile for all but cheap trips and "week-end" excursions, and apparently disregard the broad hint which the profitable results of these deviations from the standard charge afford, viz., that by reducing the ordinary fare to, say, a halfpenny per mile, they would probably, if not certainly, get three persons to travel where they now get but one. They appear to consider the penny a mile as "bed-rock," and that any departure from it is to be regarded more as a benevolent concession, or hazardous, if not reckless, transaction, than as sound and lucrative business. At the time that the "Parliamentary" fare was established, now more than fifty years ago, it was vehemently opposed, and mainly on the ground, then largely prevalent, that the "cost of conveyance" was a fixed figure. It was not then seen, as it is now, that far from being fixed, the cost of moving passengers or hauling goods varies up or down with the volume of traffic dealt with. Every tyro in railway policy now knows as the alphabet of his business that if it costs, say, x to move 100 passengers, it does not cost $5x$ to move 500. The penny a mile has long since been found to spell anything but ruin. No railway manager would for a moment think of increasing it. But how many of them can see the mine of wealth which lies waiting for those who will materially reduce it?

The absence of systematic and detailed statistics for the railways in the United Kingdom in a large degree accounts for the timidity, or we may call it conservatism, of their management. There are probably but few of our railway managers who are in a position to unhesitatingly quote the prime cost

of moving a passenger or a ton of goods, as derived from the operations of any single year, or could do more than guess at the cost of running expenses per train-mile; while the outlay per passenger-mile or per ton-mile, which would include charges shown separately for each department, would be to him no more than as a dream of perfection, or perhaps as a nightmare of embarrassment. Yet, if we turn to the statistics annually offered for the American railways, or, better still, for the Indian railways, we find that for each system, under separate administration, there is an invaluable review of its yearly operations in every detail, and for each department, and in a form so clear as to render the results on any one line readily comparable with those of another. It is due in great measure to these statistics that the rates and fares on Indian railways are probably the lowest in the world and at the same time eminently profitable. Taking as an instance the East Indian Railway, the figures for 1899 show that in this year the line carried a total of 18½ million passengers, of which 17 millions were of the third or lowest class; that the average number of passengers in a train of all classes was 228; the average distance travelled was 61 miles; the cost of hauling one passenger one mile was one-eighteenth of a penny, and the fare charged one-fifth of a penny per mile, all debits included. Now, it may be readily allowed, in comparing the fixed charges—for operation only—and the running charges on this line with those of some of our leading English lines, that the East Indian has some points in its favour; but these, after all, are as nothing in face of the fact that if the average income of the third-class passenger in England is taken, say, at £15 a month, that of the same class in India may be taken, and liberally, at no more than 15 shillings; that is to say, that in order to induce any passenger traffic at all, and one that was worth considering, the Indian railways have had to come down to rates which the English railway manager would have imagined impossible. They have found, however, that by moving very large numbers at very low fares the result is most profitable, and, in face of such figures as are given above, it is but reasonable to ask whether the penny a mile must be continued as the standard fare in the United Kingdom, *i.e.*, for ordinary journeys. The reply might be that the penny pays, and that any materially lower fare may not. Yet against this we have the fact that fares approximating to a half-penny a mile, or indeed less, on the Central London, the District Railway, and the Glasgow tramways, are, with large numbers, not only possible in a fiscal sense, but that, in the face of keen competition, it is the only way of getting the traffic. From such facts it seems fair to expect that if the half-penny a mile were adopted generally on English railways, for all journeys, instead of the penny, thousands, or rather millions, would largely increase the number of their railway journeys, and that, moreover, an entirely new stratum of travellers would be reached. It is further to be remembered that a development of passenger traffic is now well understood to bring with it a corresponding improvement in goods traffic.

It is not overlooked that the settlement of this question is no small matter, for it must be tested fairly, and on a sufficiently large scale, while the experiment may, or perhaps must, involve a considerable expenditure on additional rolling stock for at least main lines. The area on which the experiment would seem at first most likely to prove successful is on the

railways serving the seaboard round London. There lies a field for the enterprising manager such as exists nowhere else in the world—a city of, let us say, five millions of sea-loving people at one end and the sea at the other. Yet there we find, at any rate for the third-class passenger, a poor and unpunctual service, a class of rolling stock which, until quite lately, was almost the worst in the country, and fares which, to the bulk of the people, make a visit to the seaside a rare luxury, while it should, and could, be the commonest holiday jaunt for the Londoner. With fares reduced to a halfpenny a mile, with a fast direct service, and with ordinarily decent carriages, thousands upon thousands of people who now perhaps go down to the sea once in the year would come to regard such a trip with but little more hesitation than those who now fill the Pullman cars to Brighton and elsewhere. What can be more obviously prohibitive to the great lower and lower-middle class than the present ordinary return third-class fares to Brighton (8*s.* 5*d.*), to Dover (12*s.* 11*d.*), to Margate (12*s.* 4*d.*), or Hastings (10*s.* 1*d.*), all at the inevitable penny a mile, and none of the places much more than 70 miles from London. At a halfpenny rate, and with an ample service of quick through trains, the present passenger traffic could probably be quadrupled, more especially if facilities for through booking were arranged with the District Railway; indeed, it is more than likely that it would pay to make entirely new direct lines, electric possibly, for no other purpose than to serve a through passenger traffic between London and the sea coast. But for the railways round London, at least, the halfpenny fare need not be confined to seaside traffic. It would effect a great development of suburban traffic, more especially on the shorter distances, and induce a far greater movement of the rural population to and from towns and villages from distances of 50 to 60 miles from the metropolis, a movement which is now inconsiderable, and which would well repay better attention on the part of railway men.

Conservatism appears to be the key-note of the policy of our railway companies. They seem to say, "Our officials and our workpeople get their pay, the board gets its fees, and the shareholders their moderately good dividend. What more do you want?" The "more" that is wanted is some attention to the claims of the British public, more regard for the interests of the shareholders, some attempt to shake off old-fashioned ideas and to strike out in new directions. In any such attempts they should recollect that every small advantage which the third-class passenger now has, as compared with his position fifty years ago, has been simply wrung from the companies against their vehement opposition, and yet not one of these would now think for a moment of returning to the old *régime*. The "Parliamentary" train was discouraged by making it almost impossible for the third-class passenger to effect any long journey in daylight, even although he was expected to start at cock-crow and was made to get out and wait at junctions; though even when his train arrived there might be no room for him. Conveniences of any kind, even for refreshment, were not even contemplated for this lowly type of traveller. Again, when the Midland Company, in 1872, boldly started to carry third-class passengers by all trains, the other companies, especially the Great Western, lagged behind for a long while, and even to this day the South-Eastern and Chatham Companies run some trains either with first and second

only or with an extra charge for third class. Again, the substitution of two classes for three, proposed or advocated by Mr. Gladstone so long ago as 1874, which has already been amply proved to be both politic and profitable, has not as yet been adopted generally, though it grows slowly. So it is with reduction of fares; the fare and a half, and the single fare, or, in other words, the halfpenny per mile, are already well to the front for trips and excursions, but for these only, though they show without doubt that full trains at these rates are distinctly remunerative. There are, in fact, but few lines on which the actual cost of carrying passengers in full trains can be much more than half a farthing per head per mile, yet, though our railways have taught us to travel, they have not learnt their own lesson, which is to offer the necessary inducements to extend the habit. They go on with the same old "penny a mile," as if there were divine revelation in the figure, and as if our railway boards were not men of business but mere ornamental pluralists. In some cases, if not in many, the boards are held down by the inertia of their managers, as was notoriously the case on the Great Western, when in the able but very conservative hands of Grierson. His type is unfortunately still too common, and for the reason that by the time a man has worked up from the bottom of the ladder to the position of manager, he has too generally and not unnaturally lost his vigour and the spirit of enterprise. His policy is to let well alone; the better or the best may be left to others to try for. On the other hand, there are doubtless many younger men who, if given reasonable latitude of action, would soon show that the true policy of the administration of a railway is, as much as in any other industrial undertaking, to venture, to move forward, even if slowly, and to be content, not merely when they have met a demand forced on them, but when they have introduced facilities which will induce a further demand.

One acknowledged difficulty in carrying out a general and considerable reduction in third-class fares lies in the want of sufficient yard and platform accommodation at many of the older principal stations, and especially in London, if, as is almost certain, the halfpenny per mile fare led to trebling the number of travellers in the third class. At many of the smaller stations, as, for instance, on the Brighton and the South-Eastern and Chatham lines, the same difficulty would be experienced, though this difficulty is after all almost entirely one of money, and is one that can be met gradually and tentatively as the demand develops. A similar but probably less immediate obstacle will be found in the need for a large increase in the rolling stock. But neither these nor other difficulties would stand in the way for long when experiment had satisfactorily established that the reduction of fares would be profitable.

DISCUSSION.

The SECRETARY[1]: Having read the paper in the absence of Mr. Horace Bell, I may say that since I have been here I have been rather amused to find that the Glasgow and South-Western Railway Co. have adopted a lower fare than the generally recognised one. Those of us who have been at this Congress have probably been very pleased to find that they could obtain vouchers enabling them to travel a double journey for one and a quarter the cost of a single journey. As I have the pleasure of staying about an hour and a half's journey out of Glasgow, I considered this was to some extent a very pleasant concession. I presented my voucher at the ticket office on the first day; the man looked at me and said, "I do not quite see what advantage this is; it gives you a return ticket for 7*s.* 6*d.*, which is our ordinary fare." (*Laughter.*) It therefore appears that what was thought a very great concession—at any rate in the case of one railway company—is looked upon as "good business" by the company I have been travelling by.

Sir GUILFORD MOLESWORTH: I have always held the opinion that a railway should not be looked upon by the Government of any country as a money-making concern, but as an instrument for developing the resources of the country; and I have always urged this policy upon the Governments with which I have been connected. We had great difficulty in India in persuading the railway companies to adopt the policy of low rates. As Mr. Bell has said, the railway passenger fares on the Indian railways are, in the lowest class, one-fifth of a penny per mile, and they have been entirely successful. We have gone still further with the freight charges for goods. We constructed a State railway through the heart of the country—the Rajputana line—which to some extent competed with the other railway companies; and as the Government adopted low goods rates on my recommendation, the other companies had to reduce their rates. An enormous grain traffic was developed immediately, and we carried grain more than a thousand miles to the port of shipment. Of course we must have a low rate to enable the country to be developed in that way. This Rajputana railway of which I speak was made for political and strategical purposes, and was not expected to pay its working expenses; but it has proved to be a very remunerative line, and I believe this is due to the policy of low rates which has been adopted.

In England our railways labour under great difficulties, this country being blessed with an infatuation for that fiscal policy misnamed "Free Trade," which enables the foreigner to put produce into the London markets at lower rates than we can now bring it from our Midland counties.

I may, perhaps, be allowed to quote from a memorandum which I addressed to the Government of India some twenty years ago:—

"It has lately been laid down as a maxim for adoption that Government should as a rule divest itself of the task of working railways after they have once been constructed. Such a maxim is opposed to the main grounds on which railway construction should be

[1] Mr. R. Elliott Cooper, Member of Council Inst.C.E.

undertaken, viz., for the development of the country. Clearly the proper policy of the State is to develop the resources of the country by the lowest possible rates of carriage, and it might amply repay a Government in some instances to suffer loss in railway working, provided that by the adoption of low rates the trade of a district could be stimulated. It is easy to conceive the case of a railway unsuccessful from a commercial point of view, and yet highly remunerative to the State. A company, on the contrary, can only look to the direct return of a railway as a commercial speculation. The profit made by railway companies must as a rule be considered as taken from the general community and handed over to a select few. But this by no means represents the worst features of the case, for this profit may also be working an incalculable amount of mischief by checking the development of trade and the welfare of the country.

An argument has been advanced that refusal on the part of private enterprise to take up any railway project *is primâ facie evidence that the project is not required.* It is difficult to conceive a greater fallacy. Such an argument, if carried to its logical sequence, would have put a stop to the construction of roads in India, for roads have not as a rule yielded returns sufficient to meet the current expenses of their maintenance, far less have they offered any return as interest on the capital expended. Yet if you would venture to argue that roads are not needed, if roads had been made and worked by private enterprise, they must either have ruined their projectors or the country."

Sir WILLIAM PREECE: This is a paper on railway politics, and one of the essential elements of railway politics is finance; it is all very well for Sir Guilford Molesworth to support the Governmental management and control of railways. The management of railways in India is rather a sentimental one; it is not so in this country. Our railway companies are all great commercial concerns, and must be managed and controlled on financial policies.

The question raised by the Paper is simply the question of cheap *versus* the present dear fares; and I rather disagree with Mr. Horace Bell in his estimate of the character of our railway managers. I have had a great deal to do with railway managers, and although Mr. Grierson may have been conservative—there is an exception to every rule—I will say of other railway managers that they have shown a spirit of energy and enterprise that is worthy rather of our commendation than of our rebuke. The reason they cannot go ahead with fares is that we are trammelled by financial and fiscal traditions, which have been rapidly knocked on the head by our American cousins. The Americans have made their railways to pay; they have taken up perhaps the very worst example of a badly financed and a badly conducted line, namely, the Metropolitan and District Railway system in London, which has now fallen virtually into the hands of the Americans. Mr. Yerkes has control of the "Metropolitan District," and he is going to show us in this country how a line can be worked, as regards fares, on American principles. It will not only be converted into an electrically-worked line, but the whole of the system will be worked at one uniform fare, which I am told will be $2\frac{1}{2}d.$ Of course, every man in this room and every man in the railway world will say that it is absolute nonsense to think for one moment that a railway like the "Metropolitan" can be made to pay with a uniform fare of $2\frac{1}{2}d.$ At any rate, it is going to be tried, and we shall see the result. It will be a grand object-lesson to our managers throughout the country, and we shall teach them, or they will teach us, what really is the proper mode of working our railways, whether at high or low fares. But, mark you, it is not a mere question of a shilling *versus* $2\frac{1}{2}d.$; the secret of the success of American railways is that, whether they are worked by electricity or not, they are worked on these three principles: rapid transit, cheap fares, and frequent service; the result is that a railway is worked more like a tramway. Take

Glasgow, for instance. There is a splendid tramway service in Glasgow, which has grown with gigantic steps. Since the horses have been removed and electricity has come in, I do not know what the real figures are, but the growth has been simply enormous. These three principles of rapid transit, cheap fares, and frequent service have been carried out there; and so it will be on the "Metropolitan."

On all our big railways, the suburban parts of their systems do not pay. If they were worked by electricity, as Professor Carus-Wilson pointed out in his Paper, there would be a complete reformation. Electricity, with American ideas, is going to give us an object-lesson which will, supporting Mr. Bell in what he says in his Paper, show that there will probably be a change in the very low ebb at which our railway properties are at present in the market, and shareholders who have not touched dividends for some time will renew their acquaintance with fat dividends.

The CHAIRMAN: It appears to me that this Paper is full of good sense, and well deserving of the serious consideration of our railway managers and shareholders; and we are very much indebted to Mr. Bell for it. It is a question which is very much to the fore at present. We all think that our railways might be less conservative in their administration, and take a lesson in many things from our more enterprising neighbours across the Atlantic.

I have much pleasure in proposing a very hearty vote of thanks to Mr. Horace Bell for his Paper. (*Carried by acclamation.*)

That concludes the business of this Section, and I ask you to accord to our worthy and Honorary Secretary, Mr. Elliott Cooper, your very hearty vote of thanks. (*Applause.*)

(*The motion having been carried by acclamation, a vote of thanks was, on the motion of Mr. Hogg* [*Glasgow*], *passed to the Chairman for presiding, and the business of the Section was brought to a close.*)

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